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ENERGY CONSERVATION OPPORTUNITIES IN APPLIANCES USING ENERGY STORAGE

FINAL REPORT
November 30, 1978

Prepared by

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Elia P. Demetri
W. David Lee

ARTHUR D. LITTLE, INC.
Acorn Park
Cambridge, Massachusetts 02140

Work performed for

OAK RIDGE NATIONAL LABORATORY

Operated by

UNION CARBIDE CORPORATION

for the

U. S. DEPARTMENT OF ENERGY

Division of Buildings and Community Systems

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ABSTRACT

During this program, the use of energy storage in conventional appliances to save energy was evaluated. Fuel-fired appliances, electric appliances, and utility load leveling by energy storage on the customer's side of the meter were considered.

For each of the appliances treated, various energy storage techniques were evaluated by estimating the energy savings and the cost of the required storage system. An estimate of the commercial feasibility of each system was made based on the years necessary to pay back the cost of the storage system. In addition, when alternate approaches could be used to improve the efficiency of the appliance without energy storage, the costs of these methods were considered in the evaluation.

The analyses found that the most promising applications involved the use of point-of-use thermal energy storage for electric utility load-leveling. However, although substantial utility operating cost savings can be achieved, there may be little or no actual energy saving when all losses are considered. For applications other than load-leveling, energy savings were too small to pay back the added cost of the storage system in an acceptable time.

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CHAPTER 1

INTRODUCTION

1.1 Background

In the past a number of programs have considered different methods of improving the efficiency of appliances in order to conserve energy. Appliances have been a target for these efforts because they consume a significant percentage of energy in the nation. In 1975 residential and commercial appliances are estimated to have been responsible for 30% of the nation's energy consumption. These programs have looked at methods of improving the efficiency of the devices by modifying designs to reduce losses, using different operating conditions such as lowering thermostat temperatures, and combining functions to make the operation of several appliances more efficient. Some of these design modifications have involved the use of energy storage to store recovered energy. Utilities have explored ways of using energy storage to improve load factors by shifting space heating, air conditioning, and water heating loads to off-peak times. In this case, an energy storage system would be charged at night when demand for electricity is low and discharged to meet the demand during the day when electricity use is higher. The effect of the use of storage on the operating efficiency of some fuel fired devices has also been analyzed.

The purpose of this program is to evaluate the feasibility of applications for energy storage which have already been identified and to assess the feasibility of other systems utilizing energy storage to reduce the energy consumption of appliances either by improving their operating efficiency or by operating them off peak to improve utility load factors and efficiencies. The objective of the program is to provide a ranking of opportunities for energy storage in appliances based on their energy savings potential and to prepare RD&D plans for the more promising systems.

1.2 Program Tasks

The program scope of work called for the completion of four major tasks.* In the first task, the energy savings potential of utilizing energy storage in appliances was estimated for those residential and commercial appliances which use significant amounts of energy. Systems were ranked based on their potential to save energy. In the next task, the feasibility of the higher ranked systems was examined. This analysis was done by designing specific systems, developing cost estimates for the appliances utilizing storage, and comparing the additional cost with the potential cost savings resulting from the improved efficiency. At the conclusion of the second task, the opportunities for storage were again ranked. Based only on the criteria of potential for energy savings

* See Appendix A for actual statement of work.

considering the likely level of commercialization, none were found which warranted further development. Therefore the third and fourth tasks were abreviated. These were to identify those applications whose commercialization would be accelerated by DOE support and to develop RD&D plans for the more promising applications.

1.3 Program Methodology

The primary objective of this program was to evaluate the energy conservation potential of using energy storage in appliances. Our general approach was as follows:

- For all appliances considered, estimate the maximum energy savings which would result from the use of storage;
- For electric appliances, estimate the cost savings to a utility which would result from shifting demand off-peak;
- Estimate the cost of conceptual designs to provide the required storage; and
- Using 1978-1980 fuel costs, estimate the years required to pay back the added cost of storage.

This approach serves the immediate purpose of evaluating designs using today's technology. It also provides general estimates of the energy savings potential of storage in appliances by function. These estimates can be used to evaluate the cost effectiveness of future designs which employ new technologies.

The general methodology used during this program is shown in Figure 1.1. The program began by assembling energy use statistics on the major appliances. In those cases where an appliance used energy for functions which would require different kinds of energy storage systems, the energy was partitioned among the different uses. For example, in a dishwasher, electrical energy is used both to power a resistance heater and to drive the motor. The energy storage system which might be suitable for storing heat for drying the dishes, clearly, would be different from the energy storage system which would be utilized for storing power for a motor. Similarly, for fuel-fired appliances, energy partitioning diagrams showing the inputs, useful outputs, and losses were assembled. Finally, a ranking of appliances, based on the energy use of different components was assembled and the systems with the better potential for energy savings were selected for further analysis.

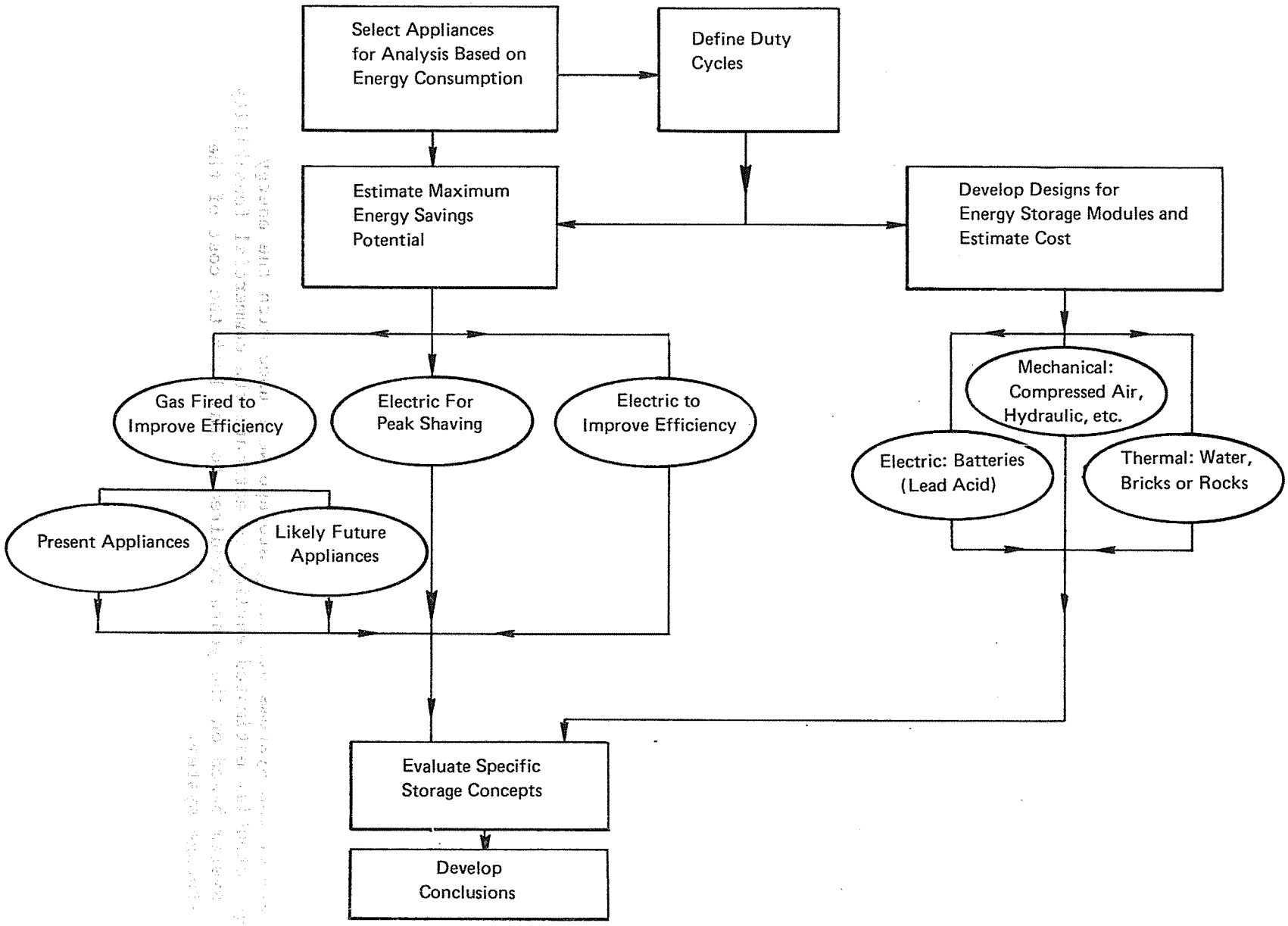

FIGURE 1.1 PROGRAM METHODOLOGY

In order to complete the analysis of these appliances, estimates of the actual daily duty cycle of each appliance were developed. Next the effect of distributing these loads throughout a utility area was estimated assuming a normal distribution of use. These individual duty cycles were also used in estimating energy savings potential and designing storage modules in later steps.

To estimate the maximum energy savings potential of these systems, the opportunities for energy storage were divided into three logical categories. These are:

- Energy storage with fuel-fired devices to improve their efficiency by reducing the losses of the devices;
- Energy storage for electrically powered devices to improve utility load factors and efficiency; and
- Energy storage for use with electric appliances to improve their operating efficiencies.

In the case of gas-fired appliances, the energy savings potential of systems utilizing storage to reduce losses was compared with the savings of other methods such as intermittent ignition devices, flue dampers, improved insulation, etc., which are currently available on commercially produced appliances.

Once the maximum energy savings potential for these different configurations had been estimated, the cost of adding the storage to the device was estimated. For this analysis, three different types of storage systems were considered. These are:

- electric energy storage with electricity as input;
- mechanical energy storage with electricity as input;
- thermal energy storage with electricity or fuel as input.

The costs of the systems utilizing storage were used with the energy savings potential estimated earlier to estimate the commercial feasibility of the system based on the years required to pay back the cost of the added storage system.

1.4 Ground Rules and Assumptions

The important ground rules and assumptions used during this program are discussed below. Others are mentioned in the text where pertinent.

In this program we evaluated ways in which the energy consumption of conventional appliances could be reduced by the use of energy storage. It did not include an evaluation of storage in advanced technologies such as solar heating, cooling, and power generation, wind turbines, utility use of storage for generating electricity to meet peaks, etc.

The General Electric Monthly Production Simulation Program was used to estimate the cost and energy savings which results from using point-of-use energy storage to reduce utility peak loads.

Inputs to this program were:

- The definition of a reference summer and winter peaking utility by specifying load curves for a weekday, Saturday, and Sunday of each month in the year and a specific generation mix without pumped storage (these data were taken from a P.S.E. & G. study (Reference 4) which developed a reference utility to study the effect of utility storage systems and from an Argonne study (Reference 20, Asbury) which analyzed point-of-use storage systems).

- 1980 Projected fuel prices as follows:

Nuclear	\$0.803	$/10^6$ Btu
Coal	\$1.606	$/10^6$ Btu
Oil	\$2.743	$/10^6$ Btu
Gas	\$4.818	$/10^6$ Btu

- Daily appliance duty cycles developed from a variety of sources including:

  - heating and cooling loads from an Arthur D. Little computer simulation using weather tapes from New York City and Albuquerque;

  - refrigerators, lighting and television use based on Arthur D. Little estimates;

- duty cycles for range/ovens, dishwashers clothes washers and dryers, and water heaters developed from References 18,19,21,22,23,25 and 26.

Since these results are for the specific reference summer and winter peaking utility described above, they will not be true for all U.S. utilities. However, they are valid as a basis for planning since they are for a representative case.

Cost estimates of thermal storage devices were based on commercially available systems. A number of advanced storage systems employing phase change materials and chemical reactions to store thermal energy are being developed. In some cases, these may offer both cost and performance advantages over current technology; however, the systems are not defined well enough at this time to be used in this program.

All evaluations were based on conceptual designs. The program involved no hardware development. In many cases, only rough cost estimates were made since the cost savings of the systems being evaluated were too small to warrant more detailed analysis.

In evaluating the economic attractiveness of a particular system, a simple years to payback criteria was used in most cases. However, in all cases the method of estimating the energy savings potential is presented so that new concepts can be evaluated.

All economic feasibility analyses were done using 1978 dollars, except in those places indicated.

The program concentrated on residential appliances. During the program we uncovered no methods of using energy storage in conventional appliances which were uniquely applicable to the commercial sector. In addition, due to the large number of different sizes of appliances used in the variety of commercial applications, disagregated energy use data by appliance type and size is not available. For example, energy use for air conditioning commercial buildings such as schools, hospitals, hotels, etc. has been estimated in general but not broken out by equipment categories such as:

- central vs room;
- air vs chilled water;
- heat pump vs air conditioner;
- unitary vs split systems.

Each such category would have a different storage configuration. We have focused on the better defined residential sector during this program. However, the results of our analysis of residential appliances and the methodology should be applicable to commercial appliances as well.

There are three major differences between residential and commercial appliances which relate to energy storage systems. First, duty cycles are different. For example, in a commercial laundry facility, energy used by washers and dryers is spread throughout the day with each appliance being run for a number of cycles. Water heater loads in restaurants correspond to meal times while hotels have early morning and late evening peaks. Second, commercial appliances are larger. Third, commercial appliances are generally more efficient and better made than residential appliances.

These differences can be used to qualitatively estimate the effect of energy storage in commercial appliances relative to residential appliances. Storage to save energy in fossil fuel-fired appliances would be less effective in commercial appliances because the large sizes, longer duty cycles, and better designs lead to smaller losses. Storage to improve the efficiency of electric appliances can really only be evaluated on a case by case basis. Air conditioners, heat pumps, and refrigerators fall into this category. Results for air conditioners and heat pumps should be similar to scaled-up residential results since duty cycles are primarily dependent on weather conditions. Both residential and commercial refrigerators and freezers have a reasonably constant duty cycle with the peak occurring during the daytime hours. Commercial units are larger and have lower losses than residential units. Therefore, commercial units should benefit less from storage than residential units.

The use of storage to reduce utility peak loads should be more effective for commercial appliances than for residential ones because more energy use is concentrated during daytime hours and larger systems have smaller storage losses on a percentage basis. The cost savings to the user will be offset to some extent by higher equipment cost. Since commercial appliances are designed for a longer life than residential units, the incremental first cost per energy saved may be higher leading to a less attractive payback. In any event, as discussed in Section 3.2, this application does not lead to a significant energy savings if utilities dispatch the generation equipment using a procedure similar to that used in the GE MPS simulation program.

1.5 Summary

During this program, we concluded that no new projects aimed at improving the efficiency of conventional appliances by using energy storage are justified. We also showed that improving utility load factors by using energy storage off-peak will save gas and oil but may not save energy.

The more promising energy storage applications involve appliances which can be used to store electricity generated during off-peak periods. Several appliances for this application are developed and offered commercially or are being developed and evaluated in EPRI and DOE programs. (e.g., water heaters and space heaters). All other applications gave energy savings or cost savings which were so small that the cost of a system to store the energy was unacceptable. In fact, when the standby losses which would result from the use of storage are considered, the savings at the utility in many cases are completely offset by the losses at the point of use.

These results are summarized in the following discussion and tables. Table 1.1 shows estimates of the savings which could result from storage of off-peak electricity. Table 1.2 compares these savings with the costs of actual or conceptual storage systems. Table 1.3 summarizes the savings from various approaches to reducing losses in fossil fuel-fired appliances. Table 1.4 deals with the savings which would result from various storage schemes in air conditioning and heating applications. Each of these is discussed below.

Table 1.1 shows the cost savings which could be passed on to utility customers who utilize energy storage systems in different appliance applications. These savings were calculated using the General Electric MPS Program to simulate the operation of a synthetic winter and summer peaking utility with the loads for these appliances shifted to off-peak hours. The results show a substantial savings when off-peak electricity is stored to meet space heating loads in the case of the winter peaking utility and air conditioning loads in the case of the summer peaking utility. The savings with water heating are also large for the longer term storage periods. The remaining applications show fairly small cost savings on a per customer basis. In general, the cost savings to the summer peaking utility are somewhat larger than the cost savings to the winter peaking utility due to the fact that the daytime peak for the summer peaking utility is more severe than that of the winter peaking utility. This results from the fact that the space heating load which constitutes the bulk of the winter peak is not coincident with system peak. The cost savings are a result of a reduction in fuel and operating and maintenance costs which result from the use of less expensive fuel and a reduction in the amount of peaking equipment required by the utility. The use of storage in this way results in a saving of gas and oil but does not result necessarily in a more efficiently operating utility system. In fact, in some cases the actual BTU's used will increase while in others the BTU's will decrease depending on the generation mix and load curve of the particular utility.

The savings shown in Table 1.1 represents the maximum incentive which could be offered to a customer of a utility to install a storage system. In order to evaluate the likelihood of commercially successful products utilizing storage for these applications, the costs of storage systems were compared with the savings which could be passed on by the utility. The requirement for additional energy due to additional standby losses were also considered.

Table 1.2 shows the results of this analysis for various types of appliances utilizing storage. Air conditioning is not included in this table as the evaluation of these systems involves not only opportunities for storage to reduce utility peaks but also to improve the efficiency of the device. The results of the analysis of those systems are described later. Of the systems shown in Table 1.2, only central space heating storage systems have a clear economic value. Distributed space heating, water heating and clothes drying systems all have a years-to-payback, based on the present analysis, which are larger than normally acceptable. However, future changes in energy cost or development of new designs may make these approaches more attractive. The remaining systems utilizing mechanical or battery systems all have years-to-payback which greatly exceed acceptable values. In fact, in some cases, the annual cost of the systems exceed any possible savings.

Table 1.3 compares the various approaches for reducing energy consumption in gas fired furnaces and water heaters utilizing storage. The analysis was restricted to gas-fired furnaces because they are the most widely used heating system in the United States, and they are more readily fitted with storage systems due to the cleaner exhaust. Shown on this table for both furnaces and water heaters are energy consumptions for a baseline unit which is representative of 1978 available units. Also shown are units which are going to be offered in the near future. Compared with these are designs which incorporate storage to reduce losses. From these numbers, it is apparent that modified systems being developed by manufacturers are cost effective. In addition, it can be seen that the cost savings which would result from utilizing storage are close to the cost savings which would result from the incorporation of other mechanisms to reduce losses in these appliances. Moreover, the cost of implementing the storage systems will be significantly more expensive than the cost of the other methods for reducing these losses.

TABLE 1.1

POTENTIAL COST SAVINGS FROM OFF-PEAK STORAGE

		Maximum Savings/Customer/Year	
		Winter Peaking * Utility ($/year)	Summer Peaking * Utility ($/year)
Refrigerators and Freezers		7.86	10.58
Water Heaters	4 hrs storage	7.38	14.27
	8 hrs storage	16.67	23.47
	16 hrs storage	28.61	38.22
Space Heaters		105.35	-
Lighting		2.02	3.24
Televisions		3.25	5.72
Ranges and Ovens		8.31	8.27
Air Conditioners (Central)		3.50	95.51
Clothes Dryers (Air)		6.98	10.80
Dishwashers (Heaters)		3.94	4.38
Clothes Dryers (Motor)		1.57	2.49
Clothes Washers (Motor)		0.89	0.87
Dishwashers (Motor)		0.87	1.00

* For a specific generation mix which is described in Appendix C.

TABLE 1.2

ECONOMIC VALUE OF APPLIANCES STORING OFF-PEAK ELECTRICITY

Application	Type of Storage System	Baseline	Cost: Storage System	Cost: Baseline	Years to Payback: Winter* Peaking Utility	Years to Payback: Summer* Peaking Utility
Space Heating	Central (Bricks)	Hot Air Furnace	960	640	3.0	-
	Distributed (Bricks)	Baseboard Heaters	1990	556	13.6	-
Water Heating	Larger Tank (120 gallon)	Standard Tank (52 gallon)	750	275	16.6	12.4
Clothes Drying	Heat in Bricks	Standard Dryer	87	-	>20(1)	15.1(1)
Clothes Washer Motor	Mechanical	Conventional	(2)	-	>20	>20
	Battery	Conventional	(3)	-	(4)	(4)
Clothes Dryer Motor	Mechanical	Conventional	(2)	-	>20	>20
	Battery	Conventional	(3)	-	(4)	(4)
Dishwasher Motor	Mechanical	Conventional	(2)	-	>20	>20
	Battery	Conventional	(3)	-	(4)	(4)
Television	Battery	Conventional	$40/yr	-	Cost exceeds savings	
Central System(5)	Battery	Conventional	2000	-	>20	>20

(1) Includes cost of standby losses at off-peak rate of 1.4¢/kwh.
(2) Different systems considered but all cost at least $100
(3) Battery, Charger, Inverter and switches required; cost greater than $80/year
(4) Battery life short so no payback on yearly basis
(5) Refrigerators and Freezers, lighting, television, and motors for dishwashers, clothes washers and clothes dryers.

* For a specific generation mix which is described in Appendix C.

TABLE 1.3

POTENTIAL COST SAVINGS FROM ENERGY CONSERVING GAS FIRED FURNACES AND WATER HEATERS

	Annual Energy Use/Appliance (10^6 Btu/year)	Cost ($)	Yearly Value of Savings at $3.50/$10^6$ Btu ($)
Furnace			
State-of-the Art (Baseline)	76	437	-
1980-1985* Designs	72	Unknown	14
Minimum Energy Use With Storage Designs*	71	Baseline Plus Storage System	18
Water Heater			
Baseline (1978)	39.3	135	-
1979 Units	32.7	155	23
Storage Units	30.9	295**	29

* 85% recovery efficiency
** Additional 80 gallons @ $2.00/gallon

Table 1.4 summarizes results for the various air conditioning and heat pump systems considered. For both air conditioners and heat pumps a baseline energy consumption was obtained. Next, various schemes utilizing storage to reduce losses were evaluated. The savings from the use of storage plus the savings from off-peak charging of the storage system were totaled to obtain an estimate of the maximum total savings potential for the various conceptual designs incorporating storage which were used to project the commercial viability of the system. The air conditioning systems considered included the use of storage which is charged at night when the outdoor temperatures are lower to reduce the energy consumption. Two different storage mechanisms were evaluated. One of these employed a duct storage unit which made it possible to obtain a higher operating efficiency. The other system utilized a remote storage system which involved the use of two heat exchangers and a resulting loss of effectiveness due to the temperature differences across the system. The use of ice as a mechanism for off-peak storage was also considered. Finally, two systems which involve a modification of conventional air conditioning cycles by utilizing thermal storage to subcool the refrigerant and to recondense the refrigerant were evaluated. For the conceptual storage designs which were used to evaluate these concepts, the years to payback associated with the savings was too great to promote commercialization of the concept.

A similar analysis was done for heat pumps. In this case, one system utilized storage charged during the daytime when the heat pump efficiency was higher to provide space heating. In addition, a credit was taken for the reduction in the number of defrost cycles required. This increased the overall operating efficiency of the heat pump system as shown. The savings resulting from this reduction in energy consumption was not great enough for the conceptual design evaluated to produce a commercially viable system.

TABLE 1.4

ECONOMICS OF ENERGY STORAGE IN AIR CONDITIONERS AND HEAT PUMPS

	Energy Use kwh/year	Savings/year @ $.04/kwh ($)	Savings from Off-Peak Credit ($)	Maximum Total Savings ($)	Years To Pay Back for Designs Analyzed
Air Conditioning					
Baseline	6245	-	-	-	-
Storage at Night with Storage in Duct	5875	14.80	95.51	110.31	>20
Storage at Night with Storage External	6447	-8.00	95.51	87.51	19
Ice for Off-Peak Storage	9445	-120.00	95.51	-24.49	N.A.
Thermal Storage Subcooler	6110	5.40	none	5.40	*
Recondenser**	5653	-9.24	47.76	38.52	>20
Heat Pump					
Baseline	12,560	-	-	-	-
Storage in Daytime Discharge at Night	12,060	20	none; charged on peak	20	>20

* No system with proper thermal characteristics identified

** Compared with modified baseline having 5422 kwh/year consumption

CHAPTER 2

INITIAL SELECTION OF APPLIANCES

2.1 Introduction

This program began with the selection of the appliances to be considered during the course of the program. This initial selection was made on the basis of the energy consumption of the appliances involved. The breakdown of the energy consumption for residential appliances is presented in Table 2.1 for the year 1970. In this table, the appliances are ranked based on primary energy consumption. In general, the breakout of energy use shown is consistent with that presented in other documents. For example, also shown in Table 2.1 are energy use estimates for the year 1970 made at The Oak Ridge National Laboratory (Reference 2: ORNL-Hirst). The ORNL total energy use is slightly less than the energy use projection developed for appliances shown in the Arthur D. Little, Inc., listing.

Table 2.2 shows the saturations of the various appliances used in order to generate this data. These are drawn from a number of sources and are described in more detail in Appendix B.

Initially, we planned to select only those appliances which consumed more than 10^{14} Btu's per year. However, it was decided to incorporate all of the appliances shown because the types of energy storage systems which would be appropriate for the different applications are different in many cases, and the appliances which consume a small amount of energy are the only ones which would be suitable for a battery type storage system for off-peak use. If commercial appliance energy use is added to the residential energy use given in Table 2.1, the ranking of appliances changes; however, no additional candidates for analysis are found.

In order to evaluate the potential for energy storage in appliances, it is necessary to break the energy use down in more detail because different kinds of energy storage systems are appropriate for different kinds of energy uses. For example, since a gas dryer uses electricity to power the motor and gas to heat the air to dry the clothes, different types of storage systems would be required. In fact, storage of electrical energy would be useful primarily to reduce peak demands on a utility while the storage of heat input could only be useful to reduce losses in the dryer.

Table 2.3 shows the estimated energy consumption by function for the electric appliances being considered. With the energy use presented in this way, it can be seen that the storage systems treated cover energy use which is very small compared to the total U.S. energy consumption. Therefore, a program limited to these appliances considers all of those areas which would be important from the viewpoint of DOE participation in future development programs.

TABLE 2.1

1970 RESIDENTIAL PRIMARY ENERGY USE**

	ADL (10^{15} Btu)	ORNL* (10^{15} Btu)
Space Heating	8.90	7.89
Electric	0.54	-
Gas and Oil	8.36	-
Water Heating	2.29	2.07
Electric	1.09	-
Gas	1.20	-
Refrigerators and Freezers	1.27	1.12
Air Conditioners	0.85	0.67
Ranges and Ovens	0.75	0.69
Electric	0.31	-
Gas	0.44	-
Lighting	0.47	0.82
Televisions	0.42	-
Clothes Dryers	0.41	-
Electric	0.34	-
Gas	0.07	-
Dishwashers***	0.10	-
Clothes Washers***	0.09	-
Others	-	1.18
TOTAL	15.55	14.44
Number of Dwelling Units** (10^6)	64.4	63.4

*Reference 2 (ORNL-Hirst)

**Includes single family, duplex, mobil homes, and low-rise (20 units) apartments.

***Excludes water heating

TABLE 2.2

1970 APPLIANCE SATURATIONS IN SINGLE FAMILY RESIDENCES*

APPLIANCE	ELECTRIC	GAS	OIL	TOTAL
Refrigerators and Freezers	1.32	-	-	1.32
Water Heaters	0.28	0.55**	0.06**	0.89
Space Heaters	0.07	0.74	0.19	1.00
Lighting	1.00	-	-	1.00
Televisions	1.83	-	-	1.83
Ranges and Ovens	0.46	0.52	-	0.98
Air Conditioners (Room)	0.36	-	-	0.36
Air Conditioners (Central)	0.11	-	-	0.11
Clothes Dryers	0.37	0.16	-	0.53
Dishwashers	0.28	-	-	0.28
Clothes Washers	0.71	-	-	0.71

*Reference 1: Integrated Appliances, except as indicated

**Reference 2: ORNL-Hirst

TABLE 2.3

SINGLE FAMILY ELECTRIC APPLIANCE ENERGY USE BY FUNCTION

Appliance	Annual Primary U.S. Energy Use (10^{14}Btu)	Point of Use Energy Use Per Appliance* (10^{6}Btu)
Refrigerators and Freezers	11.4	5.6[1]
Water Heaters	9.4	21.9[1]
Space Heaters	4.8	45.7[1]
Lighting	3.9	2.5[1]
Televisions	3.4	1.2[2]
Ranges and Ovens	2.8	4.0[1]
Air Conditioners (Room)	2.4	4.4[1]
Air Conditioners (Central)	2.4	13.9[1]
Clothes Dryers (Air)	2.4	4.2[2]
Dishwashers (Heater)	0.8	0.85[2]
Electric Clothes Dryers (Motor)	0.4	0.63[2]
Clothes Washers (Motor)	0.3	0.31[2]
Dishwashers (Motor)	0.1	0.11[2]
Gas Clothes Dryers (Motor)	0.08	0.34[2]

* Number of single family houses - 46.3 million

1. Reference 1 (Integrated Appliance)

2. Reference 3 (FEA/NBS)

The sources for the numbers presented in Tables 2.1 through 2.3 are indicated on the tables. In some cases, numbers obtained from these references were modified or expanded in order to provide the level of data required for this analysis. Appendix B presents data sources and the derivation of the data presented in these tables in more detail.

CHAPTER 3

ESTIMATING MAXIMUM ENERGY SAVINGS POTENTIAL FOR DIFFERENT STORAGE SYSTEMS

3.1 Introduction

After selecting the appliances to be considered in this program, we made estimates of the maximum energy savings potential which could be obtained by incorporating storage in appliance designs. These energy savings can come from three different sources. First, for gas fired appliances, energy storage can be incorporated to improve the operating efficiency of some of the appliances. Second, for electrically powered appliances, energy storage can be incorporated to permit the devices to be operated using electricity generated during off-peak periods. In this case, a storage device would be charged using electricity available at night, and the device would be operated drawing energy from that storage system during the day. Third, energy storage systems can be used with electrically powered devices to improve their efficiency. If the storage is such that it can be charged at night and provide for off-peak operation as well as improved efficiency, the economic incentive for the use of this system will be greater than for either application individually.

During this project, the effect of point-of-use thermal storage on the gas utilities was not considered. Although the use of thermal storage in electric residential and commercial appliances may have a significant impact on the electric power industry, thermal storage in gas appliances would not have a similar impact on the gas utilities because of the characteristics of the natural gas supply system. The primary difference between the two lies in the fact that gas can be readily stored while electricity cannot and must be generated on demand. The pertinent gas supply system characteristics are as follows (Reference 5: FPC).

- Central storage of gas is efficient and relatively inexpensive because it can be stored in empty gas wells, dry oil wells, aquifers or in a liquefied state.

- Natural gas can be stored in gas transmissions and distribution pipelines by "line packing" (storing extra gas at higher than usual pressure in the transmission line during off-peak hours to meet daily peaks).

- Propane and imported liquefied natural gas can be inserted in the pipeline at almost any location and mixed with the pipeline gas in order to augment supplies during unusually high peaks in the demand.

Thus, neither central storage nor transmission and distribution to meet daily peaks are significant problems for the gas utilities.

A shift to the use of devices to store off-peak electricity has an indirect effect on the gas utilities since the electric power utilities use a mix of different types of generation equipment, which require different fuels, in order to supply the variable load. In many regions, the use of energy storage allows the demand to be shifted from the peak hours when the incremental demand is met by premium fuels (e.g., natural gas) to the off-peak hours when the incremental demand is met by more abundant fuels (e.g., coal). Consequently, less of the premium fuel (e.g., gas) is consumed in meeting the peak. In these regions, a change in electric power generation mix will impact the consumption of gas.

The remaining sections in this chapter discuss in detail the energy savings which can result from storage in appliances. Chapter 4 describes storage system costs for the different applications and compares the value of the energy saved using projected energy prices to the estimated cost increase associated with the incorporation of storage.

3.2 Energy Storage for Peak Shaving

Figure 3.1 shows schematically the approach used in estimating the energy savings and the cost savings associated with the use of storage for reducing peak loads for specific utilities. These estimates were obtained by using the General Electric Monthly Production Simulation Program (GE MPS) to calculate the fuel actually required and the cost of producing electricity assuming various types of appliances were equipped with storage. This was done for both a winter peaking and a summer peaking utility.

This effort began by defining a baseline load curve for a summer peaking and a winter peaking utility over a one year period. The summer peaking utility load curve was based on data from Reference 4 (PSE&G) and the winter peaking utility curve was derived by scaling the load curve in Reference 20 (Asbury) to give a representative peak load.

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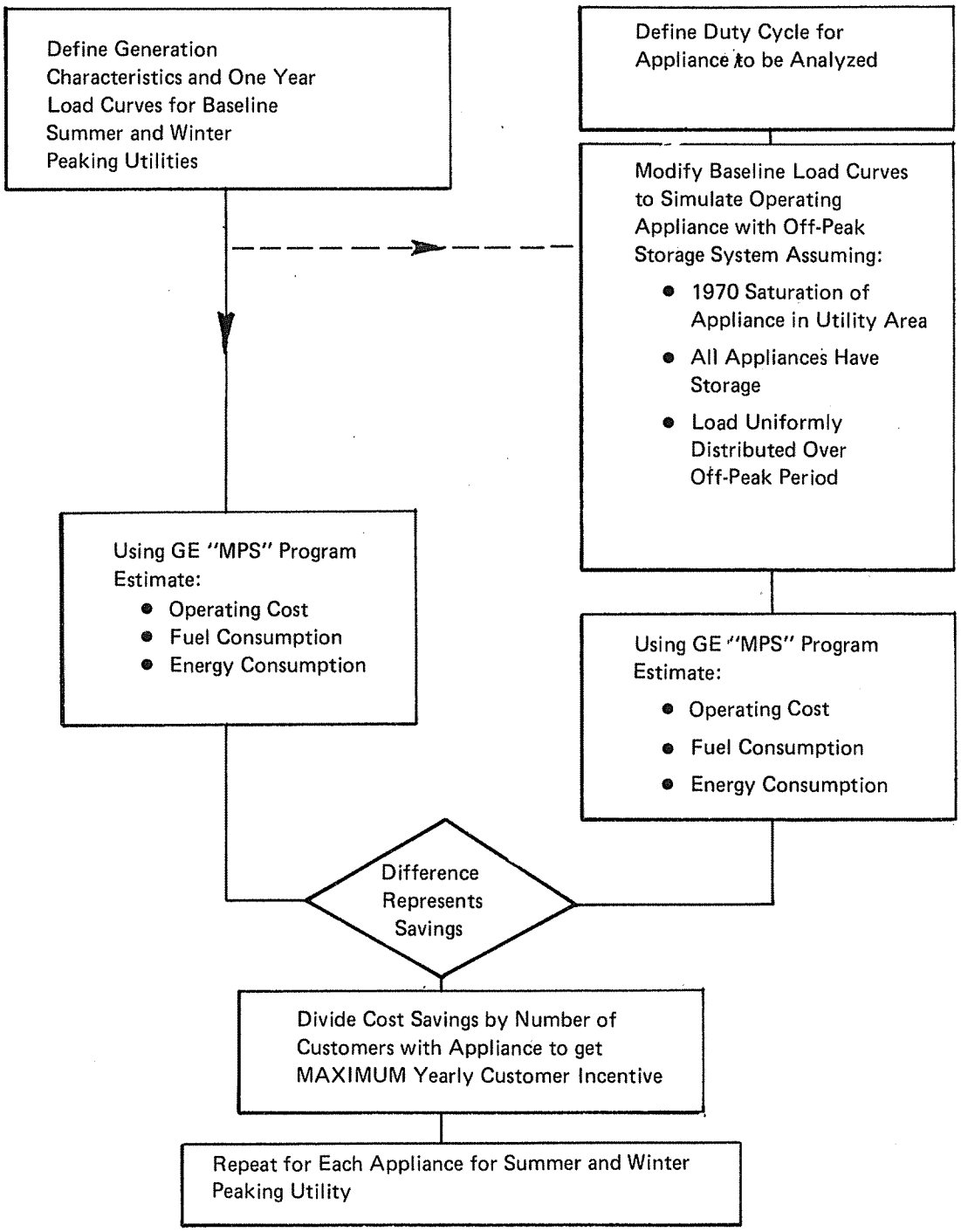


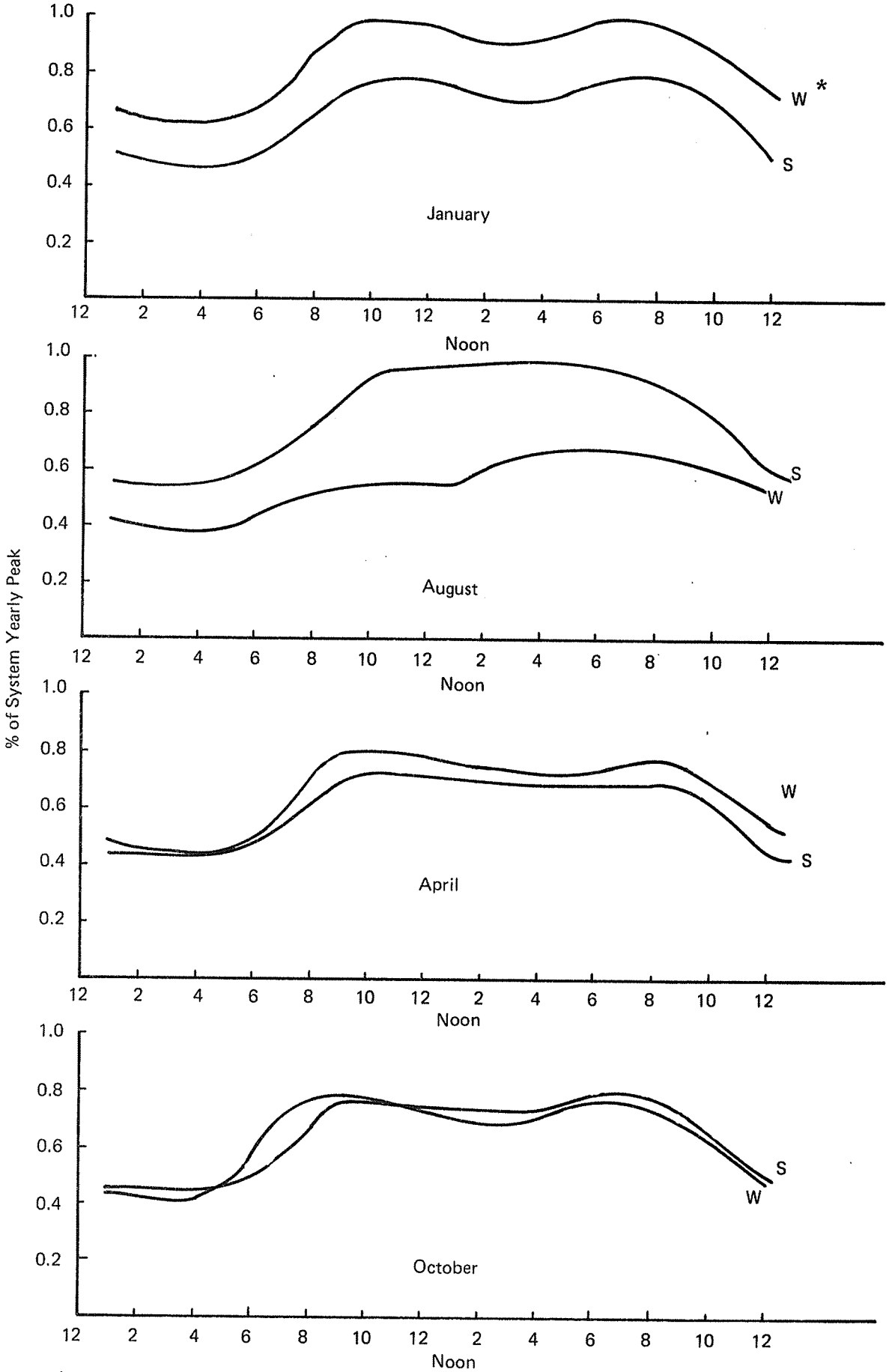
FIGURE 3.1 METHOD OF ESTIMATING POTENTIAL SAVINGS

(Appendix C contains detailed loads for the twelve months considered for both of these cases). The yearly peak for the summer utility was 6,100 megawatts and for the winter peaking utility 6,000 megawatts. Figure 3.2 presents in graphical form the load curves for weekdays for the summer and winter peaking utility for selected months showing the maximum demands in the winter and the summer and representative spring and fall curves.

The generating characteristics of a typical utility including the type of equipment, maintenance schedule, minimum downtime, etc. were also specified for the baseline utility. These were input to the General Electric Monthly Production Simulation Program (See Appendix D for a description of program) and operating characteristics on an hourly basis for a complete year were obtained. Appendix C summarizes results of these simulations for the baseline cases (summer and winter). From this program we obtained the actual fuel required in terms of pounds of nuclear fuel, tons of coal, barrels of oil and cubic feet of gas for the different operating requirements plus the cost including operation and maintenance to generate electricity during the base year.

The next step in the analysis was to define duty cycles for each of the appliances to be considered on a daily and yearly basis. Then, making the assumption that all of one type of appliance (e.g., water heaters) were equipped with storage, the baseline load curves were modified to shift the portion of the demand which would have come from the appliances to the off-peak time for each utility. This was done by distributing the energy required on a daily basis from the peak uniformly over the valley for each load curve. A different load curve was used for weekdays, Saturdays and Sundays, and the duty cycles were used to adjust the appropriate load curve based on the assumptions made concerning duty cycles of the appliances. This results in a total yearly load which is the same as that used in the baseline cases. The duty cycles used and the basis for deriving them are discussed in Appendix E. It was assumed that the distribution of appliances in the utility area was the same as that given by the saturations shown in Table 2.2 As shown below (Page 3-9), the results obtained are not sensitive to these saturations.

This method of shifting loads off-peak is equivalent to using a time clock control located at the customer's site to turn the input to an appliance off and on at a specific time. Other control strategies such as having the utility turn off and on a customer's unit from the central location as desired to control the load would also offer operating advantages. This latter approach tends to be more costly because of the added control costs. However, it offers flexibility particularly when the load curves are flatter than the unmodified load curves used in this program because shifting the larger loads off-peak may result in a peak demand in the normal off-peak hours. If a utility has control of these loads, it can stagger the times at which they come on throughout the day and night to modify the load as desired. In addition, the systems can perform other functions such as meter reading.



* Note: S = Summer Peaking Utility, W = Winter Peaking Utility.

FIGURE 3.2 SELECTED LOAD CURVES

The GE MPS Program was run using these modified load curves for each of the appliances considered for both winter and summer peaking utilities. As mentioned before if an appliance uses energy in different forms so that different storage systems are necessary, the modifications to the utility load curves were based on the appropriate storage system. For example, one computer run was done assuming that clothes dryer motors were off-peak while another was done assuming that dishwasher heaters were off-peak because a different energy storage system would be required for each application.

Using the GE MPS Program in this way, the energy and fuel required and the cost of generation on a yearly basis were obtained for each appliance. By subtracting the cost for meeting the modified load curves from the cost of meeting the baseline load curves, the cost savings to the utility associated with the use of storage in the different configurations were obtained. These cost savings were divided by the number of appliances in the field for each appliance type to obtain an estimate of the maximum cost savings which could be passed on to a customer to encourage him to purchase the storage system. Table 3.1 summarizes these cost savings for the summer and winter peaking utilities for the appliances considered. Shown in this table are the cost savings which result from a switch from one fuel type to another and the reduction in operating and maintenance costs associated with the use of different types of generating equipment plus a cost savings allowance based on the reduction in the requirement for peaking capability which comes from the reduced peak demand. This latter cost savings is an estimate of the reduction in expenses associated with lower capital equipment cost on an annual basis. It was derived from data in Reference 6 (MITRE/Metric) which indicated that the average cost for gas turbine peaking capacity is $125 per kilowatt and the average distribution cost is $3.00 per kilowatt. Using an annual cost of capital of 0.18* times the total cost gives a value of $23. per kilowatt per year. The cost savings shown was obtained by taking the reduction in the peak demand which resulted from switching the load for each appliance off-peak, multiplying it times the savings per kilowatt per year, and dividing the result by the number of customers in the utility who use that particular appliance.

For most of the applications, the cost savings potential is small, and, in addition, the cost savings for the winter peaking utility is less than that for the summer peaking utility. The latter occurs because the summer peaks are more severe than the winter peaks.

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*0.18 is a multiplier generally used by private utilities to estimate the annual cost of a capital investment. It includes a 10% discount rate, an allowance for taxes, land use, etc.

Summer Peaking Utility

Appliance	Savings in Fuel, O&M Costs* ($/Customer**/Yr)	Savings from Reduced Peaking Equipment Capital Costs ($/Customer**/Yr	Total ($/Customer**/Yr)
Refrigerators and Freezers	5.70	4.88	10.58
Water Heaters 4 hrs. Storage	14.27	0	14.27
8 hrs. Storage	19.30	4.17	23.47
16 hrs. Storage	34.05	4.17	38.22
Space Heaters	-	-	-
Lighting	3.24	0	3.24
Televisions	4.45	1.27	5.72
Ranges and Ovens	8.27	0	8.27
Air Conditioners (Central)	31.67	63.84	95.51
Clothes Dryers (Air)	10.80	0	10.80
Dishwashers (Heater)	4.38	0	4.38
Clothes Dryers (Motor)	2.49	0	2.49
Clothes Washers (Motor)	0.87	0	0.87
Dishwashers (Motors)	1.00	0	1.00

* Operating and Maintenance

** Customers with electric appliance.

TABLE 3.1 COST SAVINGS FROM OFF-PEAK STORAGE SYSTEMS

Winter Peaking Utility

Appliance	Savings in Fuel, O&M* Costs ($/Customer**/Yr)	Savings from Reduced Peaking Equipment Capital Costs ($/Customer**/Yr)	Total ($/Customer**/Yr)
Refrigerators and Freezers	3.06	4.80	7.86
Water Heaters 4 hrs. Storage	7.38	0	7.38
8 hrs. Storage	9.83	6.84	16.67
16 hrs. Storage	12.20	16.41	28.61
Space Heaters	29.90	75.45	105.35
Lighting	1.83	0.19	2.02
Televisions	1.23	2.02	3.25
Ranges and Ovens	4.97	3.34	8.31
Air Conditioners (Central)	3.50	0	3.50
Clothes Dryers (Air)	5.94	1.04	6.98
Dishwashers (Heater)	3.25	0.69	3.94
Clothes Dryers (Motor)	1.32	0.25	1.57
Clothes Washers (Motor)	0.75	0.14	0.89
Dishwashers (Motor)	0.53	0.34	0.87

* Operating and Maintenance

** Customers in utility area with electric appliance based on saturations in Table 2.2

TABLE 3.1 (Continued)

In addition to the cost savings, the savings of fuel can also be calculated by subtracting the fuels used for the modified load curves from the fuel used for the baseline case. These differences are summarized in Table 3.2. In all cases the use of storage reduced the amount of oil and gas used and increased the amount of coal and nuclear fuel.

Although there is a significant savings of gas and oil because of modifications to the load curve, there may be no real savings of energy due to the use of storage. Table 3.3 shows, for the summer peaking utility, the change in the amount of Btu's used to meet the load for the systems incorporating storage compared to the baseline system. In some cases, more Btu's were actually required to meet the load with storage than were required without storage. This is a result of the method used by the utilities to select the generation mix at any instant. Figure 3.3 presents a curve which shows the variation in the cost of electricity generated versus quantity being generated. Also shown on this curve are several representative heat rates (energy input/kilowatt output) for the equipment which would be dispatched to meet the load. For each type of input (e.g., coal, oil, gas) there is a range of efficiencies. Because of the difference in the cost of fuel, in many cases it costs less to operate an inefficient, baseload unit than to operate more efficient peaking equipment. Thus for, example, in Figure 3.3 switching load which would have been met by on oil unit with a heat rate of 9,300 Btu/Kwh to a coal fired unit with a heat rate at 11,000 Btu/Kwh will result in less efficient but more cost effective operation. Therefore, an energy savings may not result from an improved load factor even though utility operating costs will be reduced. However, there will always be a reduction in the amount of oil and gas used.

As mentioned above, these data were obtained for an appliance inventory based on 1970 saturations. The present saturation of electrical appliances is greater than the 1970 level. However, this does not result in an increased cost savings per unit installed with storage because each new unit results in a lower cost savings to the utilities than the previous unit. This results because the most costly hour of operation is that which occurs on the peak of the peak day. The first increment of storage is the most cost effective in terms of savings to the utility because it reduces the peak. This effect can also be observed from Figure 3.3. This curve demonstrates graphically the reduction in cost effectiveness of additional storage units. Since each additional storage unit is incrementally less cost effective, adding more storage units will reduce the savings which can be passed on to the user.

In summary, this analysis has produced an estimate of the cost savings which can be associated with the use of storage for the significant household appliances. This is the savings for the reference utility chosen for this study. In some cases, depending on the load curves and generation curves a greater savings may result while in other cases a smaller savings can be expected. However, this savings should be typical of the national average since the reference utility characteristics were developed by PSE & G to evaluate storage systems on this basis.

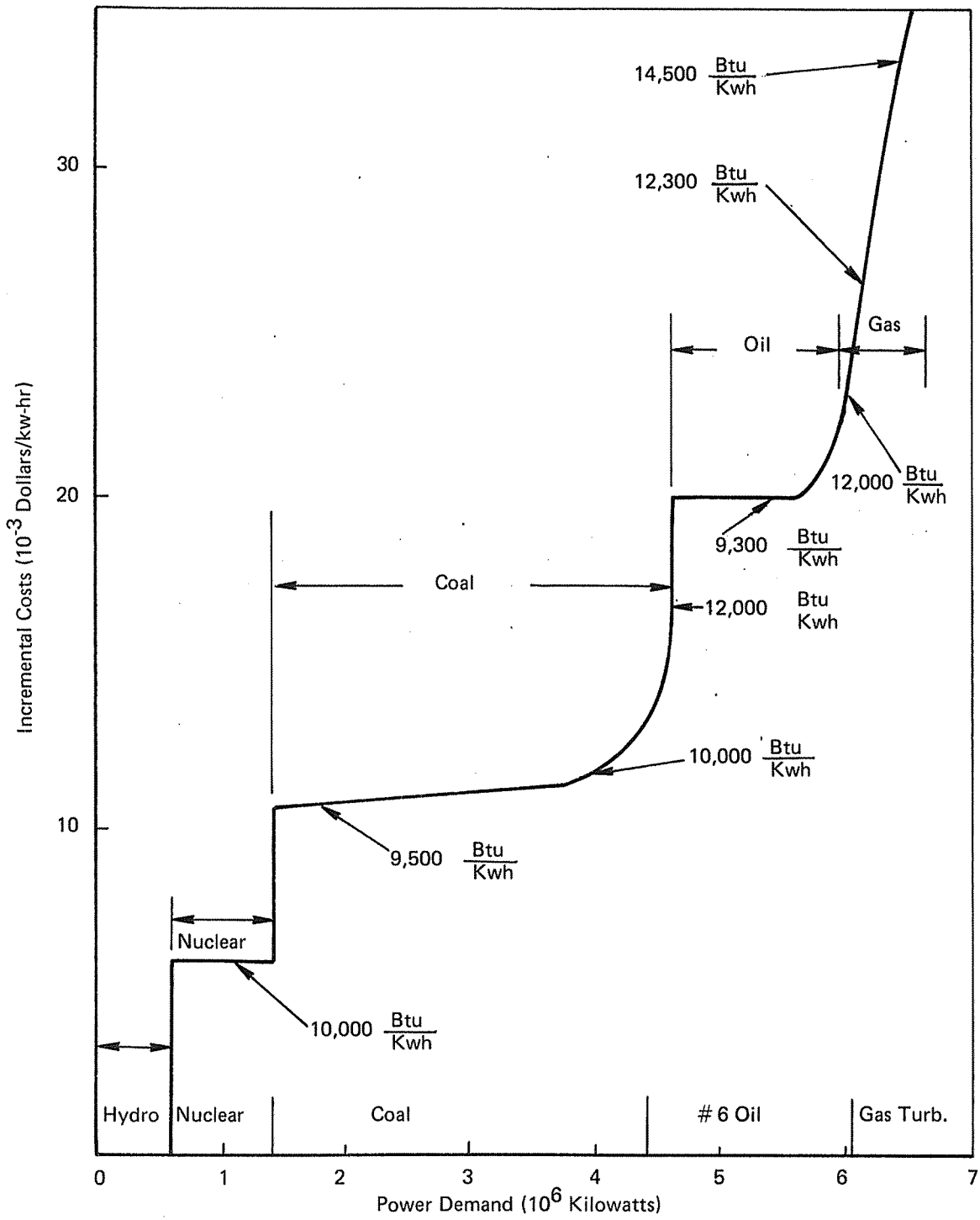
	SUMMER PEAKING UTILITY				WINTER PEAKING UTILITY			
	COAL (Tons)	OIL (bbl)	NUCLEAR (lbs)	NATURAL GAS (Mcf)	COAL (Tons)	OIL (bbl)	NUCLEAR (lbs)	NATURAL GAS (Mcf)
BASELINE Total Use	6161183	14486870	82823232	3332025	5972336	12451678	82823233	2584348
	CHANGE FROM BASELINE				CHANGE FROM BASELINE			
APPLIANCE								
Dishwasher	9717	(33489)	1	(126669)	18207	(48666)	-	(69855)
Range & Oven	166312	(583617)	1	(612173)	105703	(337674)	1	(463510)
Refrigerator (18 hr)	375584	(1107302)	1	(1750423)	184143	(497583)	-	(1111219)
Clothes Dryer								
Air	159987	(589644)	1	(880121)	89917	(300096)	-	(556553)
Motor	30267	(182861)	-	(312403)	20623	(64707)	1	(123506)
Clothes Washer	56740	(166349)	1	(358048)	32188	(94804)	-	(200130)
T.V.	219637	(678358)	1	(954996)	92859	(365079)	-	(601278)
Lighting	176434	(598221)	-	(471648)	79843	(217962)	-	(511194)
Water Heating 4 hrs.	206219	(681932)	-	(676363)	88704	(227981)	-	(536061)
8 hrs.	247248	(899999)	1	(975578)	142004	(423382)	(383)	(837109)
16 hrs.	343762	(1504007)	1	(1927801)	88198	(166325)	(84817)	(1096781)
Space Heating					70934	(112285)	-	(884360)
Air Conditioning	145370	(342775)	-	(1190471)	54948	(256174)	(827)	(96452)

* Reduction

TABLE 3.2 FUEL SAVINGS FROM OFF-PEAK STORAGE SYSTEMS

Appliance		Summer Peaking Utility Percent Change in Btu's with Storage
Refrigerators and Freezers		-0.13
Water Heaters	4 hrs.	+ .03
	8 hrs.	-0.00
	16 hrs.	-0.05
Space Heaters		-
Lighting		+ .02
T.V.		+ .05
Ranges/Ovens		+ .04
Air Conditioners (Central)		+ .09
Clothes Dryers (Air)		-0.01
Dishwashers (Heater)		+0.01
Clothes Dryers (Motor)		-0.04
Clothes Washers (Motor)		-0.00
Dishwashers (Motor)		-0.01

TABLE 3.3 EFFECT OF STORAGE ON TOTAL ENERGY CONSUMPTION



(*Based on data in Reference 4; PSE&G)

FIGURE 3.3 INCREMENTAL COSTS AS A FUNCTION OF DEMAND FOR THE REFERENCE POWER POOL*

3.3 Energy Savings Potential from Utilizing Storage in Fossil Fuel-Fired Appliances

In order to evaluate the energy savings potential of storage fossil fuel-fired appliances, we first considered the types of losses associated with the four appliances considered and then developed different storage techniques for reducing these losses. The appliances considered in this section are:

- space heaters;
- water heaters;
- gas clothes dryers;
- gas range/ovens.

Table 3.4 summarizes the energy partitioning for these four appliances on an annual basis.

For space heating the energy use is broken out by type (boiler refers to systems which utilize hot water for heating and furnace refers to the systems which utilize hot air). The bulk of the systems actually in use are gas furnaces and oil boilers. In considering the uses for storage with these systems we have also considered alternative mechanisms for reducing the same losses. New designs for space heating units and for gas fired water heaters reduce or eliminate many of these losses by using reasonably inexpensive approaches. In order for storage to be a commercially viable alternative, the system employed must cost less than these other systems or must reduce the losses even further.

The losses shown for space heaters in this table originate as follows:

- Pilot losses come from the use of a standing pilot for ignition.
- Standby draft losses come from convection of heated air up the chimney when the burner is not operating. This air leaks into the flue or enters the normally opened passages.
- Transient losses are a result of inefficiencies in the operation of the burner when it first comes on before the unit has reached a steady state operating condition.

Typical U.S. Energy Use
(Point of Use Energy Consumption)

	Space Heating				Water Heater	Clothes Dryer	Range/ Oven
	Gas Furnace	Oil Boiler	Oil Furnace	Gas Boiler	Gas	Gas	Gas
Pilot Loss	7 *	0	0	7	5.5	-	5
Standby Draft Loss	3	1	1	3	2.0	-	-
Transient Loss	1	1	1	1	-	-	-
Intermittent Cool Down	3	10	5	10	-	-	-
Other	-	-	-	-	4.5 (Jacket Loss)	0.3 (Electric Motor)	-
Flue Loss (72% recovery)	26	28	26	29	9.3	1.6 (70%)	-
Useful	60	60	60	60	18	3.7	5
Total Yearly Consumption	100	100	93	110	39.3	5.6	10

* Note: Units are 10^6 Btu/year. Based on typical U.S. energy use per appliance. Space heating based on same useful output for different appliances.

TABLE 3.4 ANNUAL ENERGY USE PARTITIONING FOR FOSSIL FUEL-FIRED APPLIANCES

- Intermittent cool-down losses result from the cooling down of the furnace or boiler due to the natural convection of air through them when the burner is not operating. Losses are higher for boilers because of the mass of water which is also cooled.

- The flue loss is that portion of the energy which is not recovered during operation of the furnace or boiler. This energy passes directly out the flue; it is equal to one minus the recovery efficiency times the burner rate.

The useful output is that portion of the recovered energy which actually goes into accomplishing space heating. The other energy which is recovered goes into standby draft losses and intermittent cool-down losses so that the total energy recovered equals the useful output plus the intermittent cool-down and the standby draft losses.

Since the burner rate is not specified by this break-down of energy, the flue loss is calculated using the recovery efficiency by the following equation:

$$Q_f = \frac{1-\eta_R}{\eta_R} (Q_u + Q_s + Q_I)$$

where Q_f = flue losses

η_r = recovery efficiency

Q_u = useful heat recovered

Q_s = standby losses

Q_I = intermittent cool-down losses.

Gas fired domestic water heaters have losses similar to those of space heaters. The pilot and standby draft losses result from the same sources as for space heaters. "Jacket losses" refers to the conduction of heat through the insulation surrounding the water heater into the living space plus the conduction of heat through the pipes and fittings which penetrate the insultation jacketing the water heater. On a national basis some percentage of this loss is useful since it contributes to space heating if the water heater is installed in the conditioned space. However, in the summer time in areas

where space heating is not required, this is a real loss. The numbers shown represent a national average accounting for the useful portion of this loss. Since water heaters are maintained at a constant temperature, there are no intermittent cool-down losses. Flue losses result from the same mechanisms as those described above for space heaters.

Gas dryers do not have pilot lights, therefore the only losses are those associated with transmission through the insulation and losses due to incomplete recovery of the energy generated by burning the fuel. These are shown as flue losses. The energy used for gas ranges is divided between the energy for the pilot and the useful energy. The useful energy actually consist of the input which goes into the food being cook plus a percentage of the portion which goes into the air in the kitchen area. Some of the latter displaces the heating load. The balanace is a loss which is not really useful. However, the distribution of losses is only significant for the purpose of this study in so far as energy storage schemes can be devised which serve to reduce the losses.

Table 3.5 summarizes the maximum potential for energy savings which could be obtained by utilizing storage to reduce the losses described above. These systems are all predicated on the use of storage to permit continuous burner operation. Also shown in this table are energy savings which coula result from the combination of storage to permit continuous burner operation with the use of improved heat exchangers to reduce the flue temperatures to 250°F or 80°F giving a higher recovery efficiency than is common today. The use of storage to provide continuous operation reduces losses by eliminating the pilot light, standby draft losses, intermittent cool-down losses and transient losses. No potential for energy savings are shown for gas dryers as they do not use pilot lights and no other loss mechanism are present which can be reduced by storage. Ranges and ovens show an energy savings which results from the use of continuous operation to replace the pilot light.

These savings represent the maximum that could be obtained utilizing storage based on an analysis of the loss mechanisms. In practice as described in Chapter 4, it may not be possible to obtain this level of savings. In addition other mechanisms for reducing these losses are commercially available today at a significantly lower cost than that associated with storage systems. The economic attractiveness of storage systems can only be assessed from a consideration of the actual implementation of a storage system to achieve these savings plus a comparison of these systems with alternative methods for accomplishing the same ends.

Approach	Space Heating				Gas-Fired Domestic Water Heater	Gas Dryer	Gas Range/ Oven
	Gas Boiler	Gas Furnace	Oil Boiler	Oil Furnace			
1. Storage Permitting Continuous Burner Operations	27*	17	17	10	7	0	5.0
2. Storage Recovering Waste Heat to 250°F Exhaust Temperature	16	14	15	14	4	0	–
3. Storage Recovering Waste Heat to 80°F Exhaust Temperature	21	17	20	19	5.5	0	–
4. Combination of 1 and 2	39	29	29	22	12	0	–
5. Combination of 1 and 3	43	33	33	26	13	0	–

*Note: All values are in 10^6 Btu per year for each unit.

TABLE 3.5 MAXIMUM THEORETICAL SAVINGS OVER BASELINE SYSTEMS FOR VARIOUS APPROACHES

3.4 Potential Energy Savings in Refrigeration Units Through Thermal Storage

The potential for energy savings in refrigeration and air conditioning units can be evaluated by identifying the energy losses of the process. For this purpose, an ideal unit has been hypothesized as a starting point and real components (a/c compressor, heat exchangers, etc.), are added one by one to arrive at a real configuration with realistic performance. The unit efficiency is calculated to show how each component contributes to the system losses.

The change in unit energy consumption through the substitution of an ideal component for a real one can be evaluated by using Figure 3.4. This figure was based on a single collection of components and is not representative of all air conditioners. The various curves in this figure were derived by starting with the ideal case and then substituting real components to evaluate the relative significance of the various losses. This process is described in the following discussion.

Carnot

The ideal unit performance is based on the conventional Carnot cycle using outdoor and indoor temperatures except that a cold air supply temperature of 50°F is used to account for practical indoor air circulation volume flow rate limitations. In addition, the same airflow limitation is applied to the outdoor unit by assuming that a 10°F difference is maintained between condensing temperature and outdoor temperature.

Real Refrigerant and Expansion Valve

The loss in performance reflects isenthalpic (constant enthalpy) expansion process of a conventional a/c or refrigerator while the Carnot cycle is based on isentropic expansion (constant entropic) which utilizes an ideal expansion engine. Cycle efficiency was calculated using R-22 refrigerant as the working fluid at the same operating temperatures as the Carnot case.

Real Compressor

The real compressor curve reflects the following losses:

- a non-ideal motor (80%-85% efficient),
- additional suction gas superheating to provide motor cooling,
- mechanical and fluid friction losses.

Real Heat Exchangers

A finite size heat exchanger is used for both the indoor and outdoor coils. The ideal unit was based on a 100% heat exchanger effectiveness requiring an infinite size heat exchanger.

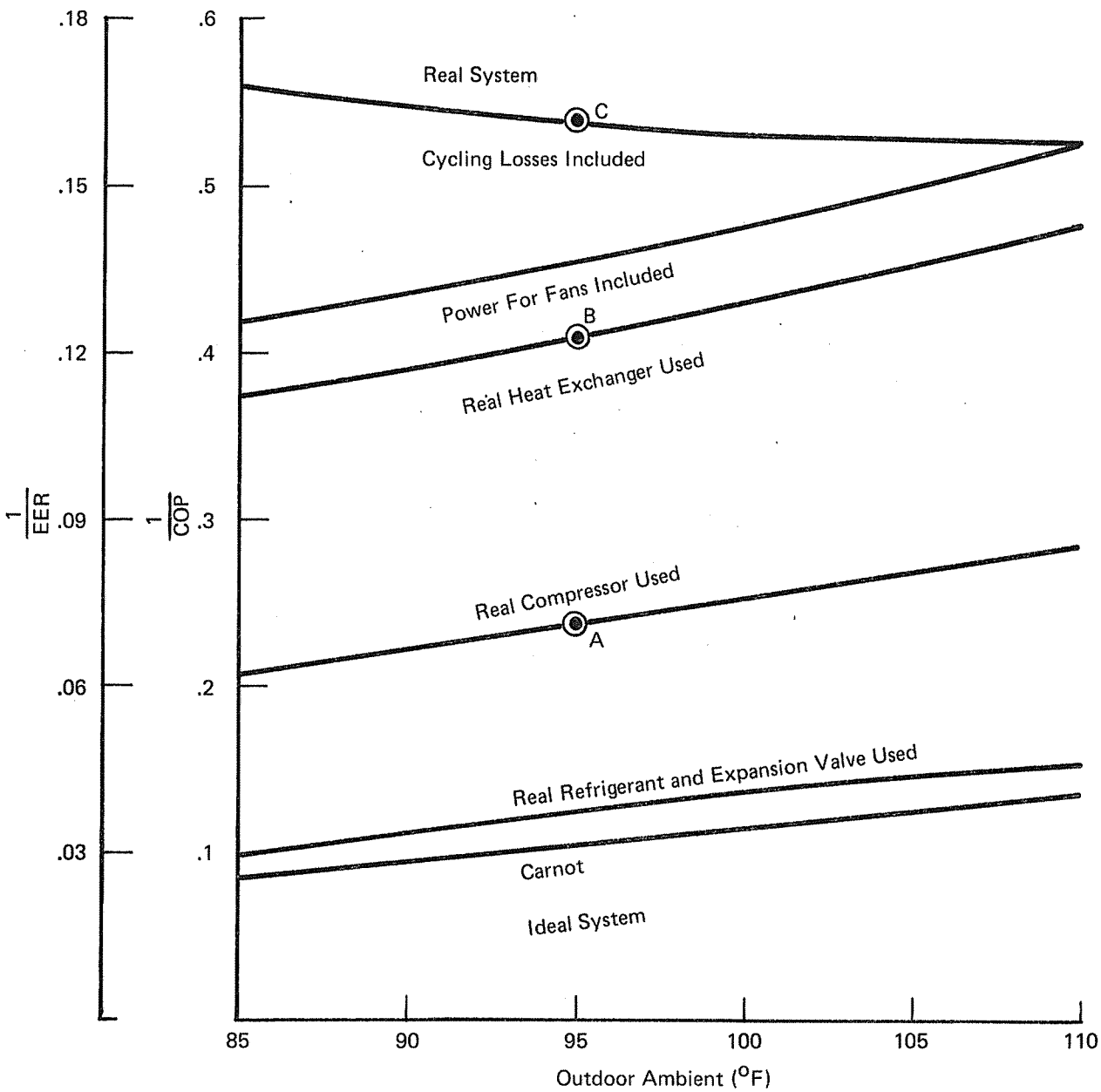


FIGURE 3.4 AIR CONDITIONER LOSS ANALYSIS

Fan Power

This curve includes the power required to move air over the heat exchangers.

Real System with Cycling

Very little data is available on the evaluation of the effect of cyclic operation on the overall system efficiency. The data presented here reflects Kelley's* data for a cycling heat pump during a/c operation. We used a straight line relation between percent run time (0% at 80°F outdoor, 100% at 110°F outdoor) and outdoor temperature to determine the percent run time which Kelley correlates to the cyclic efficiency.

The loss in performance under cyclic operation is thought to be due to:

- The loss of "coolness" stored in the indoor coil to an unconditioned space during each off cycle.
- The pumping energy required to establish refrigerant flow at the beginning of each on cycle. (Proper refrigerant/oil separation requires initial pumping during full refrigerant flow.)

The data in Figure 3.4 can be used to estimate the maximum energy-savings potential from the use of thermal storage. For example, the maximum savings from utilizing thermal storage to minimize the effect of temperature drops in heat exchangers corresponds to going from A to B in the figure.

The percent savings is estimated as follows:

$$\Delta E = Q_{refrigeration} \left[\frac{1}{COP_A} - \frac{1}{COP_B}\right]$$

where

ΔE = energy savings in the same units as Q_{ref}
$Q_{refrigeration}$ = required cooling output

The percent energy savings is:

$$\%\Delta E = \frac{\frac{1}{COP_B} - \frac{1}{COP_A}}{\frac{1}{COP_C}}$$

$$= 32\%$$

*See Reference 12, Kelley

The results of an analysis similar to that above executed for heat pumps are shown in Figure 3.5 An indoor coil temperature 30°F above ambient and an outdoor coil temperature 10°F below ambient were used with ideal components to establish the Carnot efficiency. Heat pumps require defrosting of the outdoor coil as a function of outdoor temperature. Kelley's data* for a heat pump during heating was used to estimate these losses.

This analysis establishes the bounds for energy savings in air conditioning and heat pump systems. Energy savings through thermal storage can only be obtained by designs which reduce these losses. The most obvious area in which thermal storage can have a beneficial effect is on the cycling losses of these machines. By introducing thermal storage, the compressor may be run at higher duty cycles reducing the number of cycles per day. Another area in which thermal storage may substantially improve the efficiency is by reducing the temperature differences required for the heat exchangers. This can be accomplished, for instance, by running the air conditioner at night using thermal storage and avoiding the operation of the air conditioner during the daytime under the higher outdoor air temperature, or vice versa for the case of the winter heating by a heat pump.

*See Reference 12, Kelley

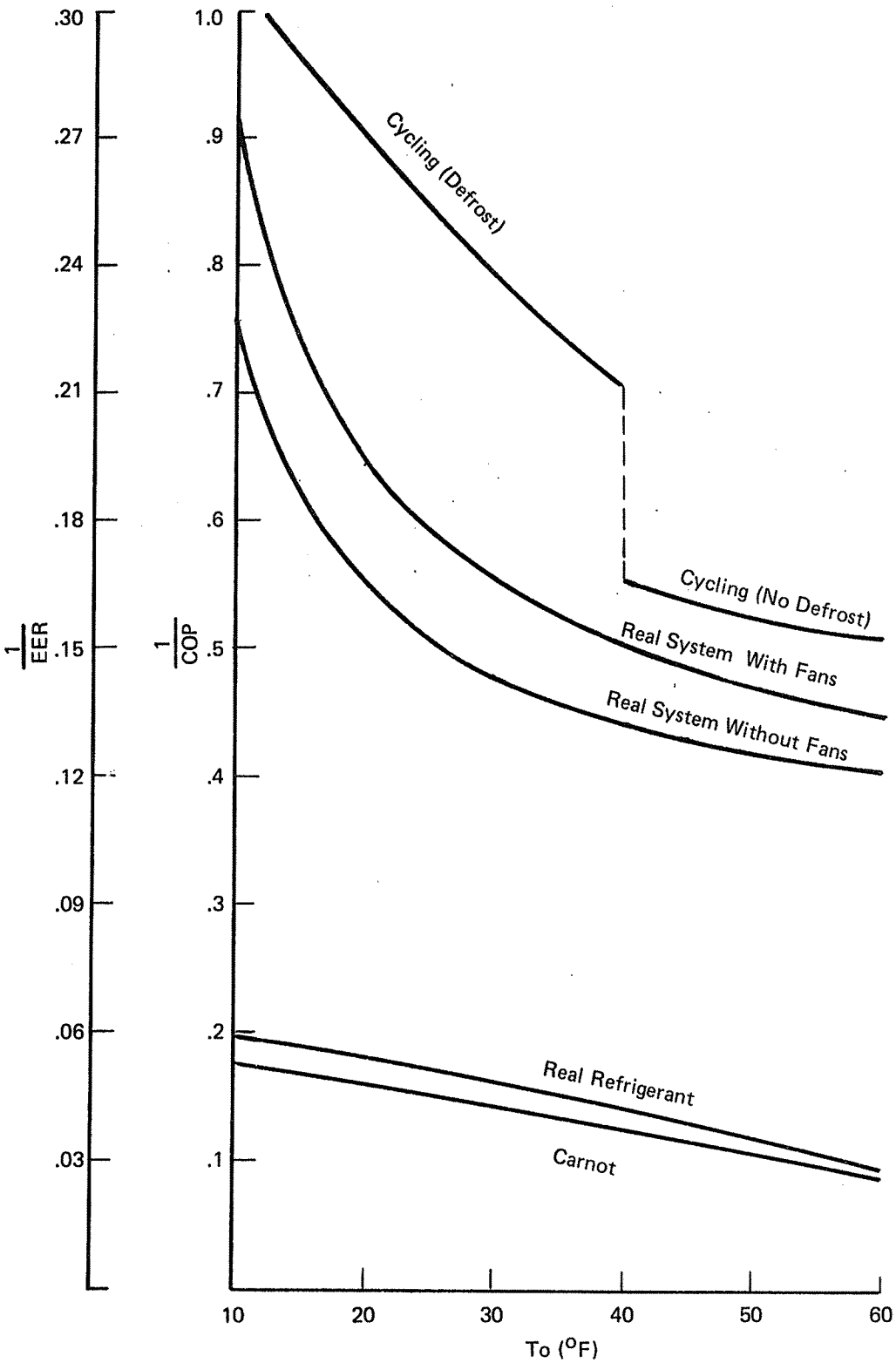


FIGURE 3.5 HEAT PUMP LOSS ANALYSIS

CHAPTER 4

COSTS OF SYSTEMS WITH STORAGE

4.1 Introduction

Previous chapters have considered the cost and energy savings resulting from incorporating storage in appliances. In order to evaluate the likelihood of the acceptance of appliances with storage in the residential and commercial market, it is necessary to estimate the cost of the appliances with storage and to compare that cost with the cost without storage and the savings potential.

In estimating the cost of storage systems, we have used storage modules based on present day technology. When possible commercially available storage systems have been used. If, in the future, the cost of these systems is reduced by the use of different techniques or energy prices increase at a higher than anticipated rate, the energy savings potential from the use of storage presented in earlier chapters can be used with the cost of the new storage system to evaluate their commercial feasibility.

In evaluating the storage systems, it is important to include the two basic types of losses which result from utilizing storage. First, there are standby losses which result from the dissipation of stored energy with time. Second, there are conversion losses. These losses would occur even if the system were charged and discharged instantaneously and relate to the efficiency of the charging and discharging apparatus. The cost savings which may result from the use of storage must be offset by these losses when evaluating the economic attractiveness of an appliance with storage. This comparison will be made in the following sections along with the discussion of the various types of storage modules.

In the following sections, we treat three different categories of appliances. First, we treat those appliances, except for air conditioners which can be used with storage to reduce peak demands on utilities. Second, we consider fossil fuel-fired appliances whose efficiency can be improved by the use of storage. Third, air conditioners are treated as a separate category because the use of storage can both reduce peak demands and improve the operating efficiency of the device.

4.2 Storage in Appliances for Reducing Peak Demands without Efficiency Improvements

Three different types of storage systems can be utilized with off-peak devices. These are:

- thermal storage;
- mechanical storage;
- electrical storage.

Thermal storage systems have been most widely considered in developments to this point. Mechanical storage systems have been evaluated for automotive purposes but have not been considered for appliances. Electrical storage generally consists of the use of lead acid batteries or advanced batteries for supplying electricity when a normal source of power is not available i.e., in standby emergency applications. The exception to this is the use of battery powered vehicles, such as automobiles, golf carts, fork lift trucks, etc. In this section the use of these three types of storage modules for storing off-peak electricity to reduce peak demands on utilities is discussed.

4.2.1 Thermal Storage Systems

From the results presented in Chapter 3, the major applications for thermal storage would appear to be space heating, water heating and air conditioning. These three applications have a cost savings which is above the other applications by an order of magnitude or more. The air conditioning application will be discussed in another section.

For space heating, several systems are presently commercially available. Some of these systems utilize bricks which are heated to approximately 1400°F to store electrical input. When heating is required, a small blower mounted in the unit circulates air through the bricks. This air is blended with cooler air drawn from the dwelling to deliver heat at the required temperature. The units generally are offered for sale with an outdoor thermostat which can be used to adjust the level of charge in the device depending on the probable demand for the space heating during the next 24 hour period.

Table 4.1 compares the cost of heating equipment for a typical residence utilizing storage heaters and standard resistance heaters for both a distributed baseboard heating system and a central heating system. The costs of the various configurations indicate that even with the significant payback for space heating, only the central systems have an acceptable payback period.

The use of storage with water heaters particularly for longer time intervals offers substantial cost savings potential. In the case of water heaters, this storage capacity is obtained by simply enlarging the size of the water tank. This leads to increased losses due to the increased surface area which can be offset to some extent by utilizing better quality insulation. Typical residential demand requires about 60 gallons of hot water per day. The use of a storage heater with a 120 gallon capacity in most cases will provide sufficient capacity.

	Utility Savings/Customer/Year ($/Yr)	Cost of Storage Unit ($)	Cost of Conventional Unit ($)	Years to Payback
Baseboard	105.35	1990[1]	556 [2]	13.6
Central	105.35	960[3]	640[4]	3.0

1. Baseboard type, Control Electric Corp., Burlington Vt., 6 room house
   20 kw total: 15 kw storage + 5 kw regular
   ([illegible] 400,000 Btu storage)

Storage		($)	($)
1	4 kw @	460	460
3	3 kw @	365	1095
1	2 kw @	295	295
Regular Baseboard			
5	1 kw @	28	140
		Total....	1990

2. Regular Baseboard (Burko List Prices)

		($)	($)
1	2 kw @	48	48
4	1.25 kw @	34	136
10	1 kw @	28	280
4	.75 kw @	23	92
		Total....	556

3. TPI, Johnson City, Tn., 400,000 Btu storage capacity, excludes ductwork.

4. 20 kw duct furnace with blower, excludes ductwork. Reference 7 (78 Means)

TABLE 4.1 ECONOMIC ATTRACTIVENESS OF ELECTRIC STORAGE SPACE HEATING IN WINTER PEAKING UTILITY

A unit presently offered by A. O. Smith is sized in this range. It has a provision for overriding a time clock control and delivering an extra amount of hot water should the unit be exhausted during the period when power is normally off. A penalty charge is made to the user if it is necessary to use power during the peak period to provide this boost to the water heater. Table 4.2 summarizes costs for these systems and indicates the anticipated payback periods for the reperesentative winter peaking and summer peaking utility.

For this comparison we have used the Conservationist model water heater. This is a unit which has been designed to reduce standby losses to less than 4 watts per sq. ft. This unit costs more than the standard builder's model water heater which has only a five-year warranty and less insulation. However, it is a valid unit to use as a storage heater because of the necessity for reducing standby losses. The standby losses on a yearly basis for a 52 gallon water heater with the additional insulation would be approximately 840 kilowatt hours. The loss for the larger 120 gallon storage tank for use as an off-peak device would be 1,390 kilowatt hours per year. This additional loss is both a real loss in terms of energy wasted, plus an additional cost to the user which partially offsets the savings resulting from the use of off-peak energy. If the off-peak energy for charging the water heater were offered at 2¢ per kilowatt hour, this would result in an additional cost to the user of $11./year. If a water heater with a higher standby loss rate were used the additional cost and energy loss would be even higher. Therefore, we feel that it is reasonable to use these improved models as the basis for considering the feasibility of the off-peak storage water heater.

Based on the data given in Table 4.2, the payback to potential customers resulting from the use of storage is not acceptable. The analysis shown in Table 4.2 has not considered any increase in operating cost which would result from the higher standby losses. In addition, we have selected an energy conserving more expensive model water heater as the baseline case. If a standard 52 gallon model water heater were used as the baseline, the cost differential and the years to payback would be even greater.

It should be noted that these results assume time clock control. If the units can be controlled by the utility and used to reduce peaks without long off periods, smaller tanks could be used. In this case there would be a lower first cost ($400) and lower standby losses than with the 52 gallon units presently used. However, this requires a more sophisticated control system.

	List Price ($)	Premium Over 52 gal Conservationist Water Heater ($)	Years to Pay Back[2]	
			Summer Peaking Utility	Winter Peaking Utility
A.O. Smith 52 gal Conservationist[1]	275	-	-	-
A.O. Smith 120 gal Conservationist	600	325	8.5	11.4
A.O. Smith 120 gal Conservationist With Load Leveling Controls (prototype units)	900	625	16.4	21.8
A.O. Smith Load Leveling Unit With 50%[3] Reduction in Control Costs	750	475	12.4	16.6

[1]10-year warranty, low energy loss water heater.

[2]Based on projected maximum savings from Table 3.1 for 16-hour storage period.

[3]Arthur D. Little, Inc., estimate of reduction which will result from redesign and automation of manufacturing process.

TABLE 4.2 COST OF OFF-PEAK WATER HEATER

Of the remaining appliances which might utilize thermal storage, clothes dryers have the highest cost savings potential. The energy use for clothes dryers is roughly the same as that for dishwashers. However, the cost savings potential is almost twice that of the dishwashers because the clothes dryer use coincides more with the peak (see Appendix E). Therefore, if the design is not suitable from a cost viewpoint for clothes dryers it is unlikely that storage applications for other short-duty cycle devices will be cost effective. Although the cost savings potential for ranges and ovens is greater than that for clothes dryers in the winter peaking utility area, this energy use is roughly equally divided between ranges and ovens which necessitates using two somewhat different storage schemes.

Figure 4.1 shows a storage module suitable for storing heat for drying clothes. It is well insulated to reduce standby losses. The storage medium is ceramic bricks similar to those used in the space heaters. These bricks are assumed to operate over a temperature range from 1300° to 300°F and the system to have a capability of delivering air up to a temperature of 200°F. Table 4.3 summarizes an estimated cost for this configuration and compares the payback periods for the winter and summer peaking utilities utilizing the device. The payback periods are marginally attractive. However, it is also necessary to evaluate the standby losses for the device. The appliances which use smaller amounts of energy have an unfortunate requirement for storing the energy used for a relatively long period of time and then using it over a short duty cycle. This leads to sizeable standby losses compared to the storage capacity of the unit. For the system shown, the standby losses have been estimated at approximately 3400 Btu's over the 14 hour period from the time the unit is charged until it is discharged. This is approximately 25% of the actual energy required to do the clothes drying. This loss is equivalent to approximately 360 kilowatt hours per year. At 1.4¢* per kilowatt hour the cost of this standby loss (360 kilowatt hours per year) is approximately $5.04 per year. This loss more than offsets the estimated cost savings resulting from the use of storage. It would be possible to decrease the standby losses by increasing the amount of insulation. However, the cost increase from the additional insulation will then make the years to payback based on the cost savings unattractive.

The effect of these standby losses suggest the desirability of developing a system which could be used to dry the clothes without standby losses. One such system would involve the use of a desiccant which was regenerated using off-peak electricity. After being regenerated, the unit would be sealed with valves until the clothes were to be dried. A typical dryer load

* Boston Edison experimental off-peak rate (1973).

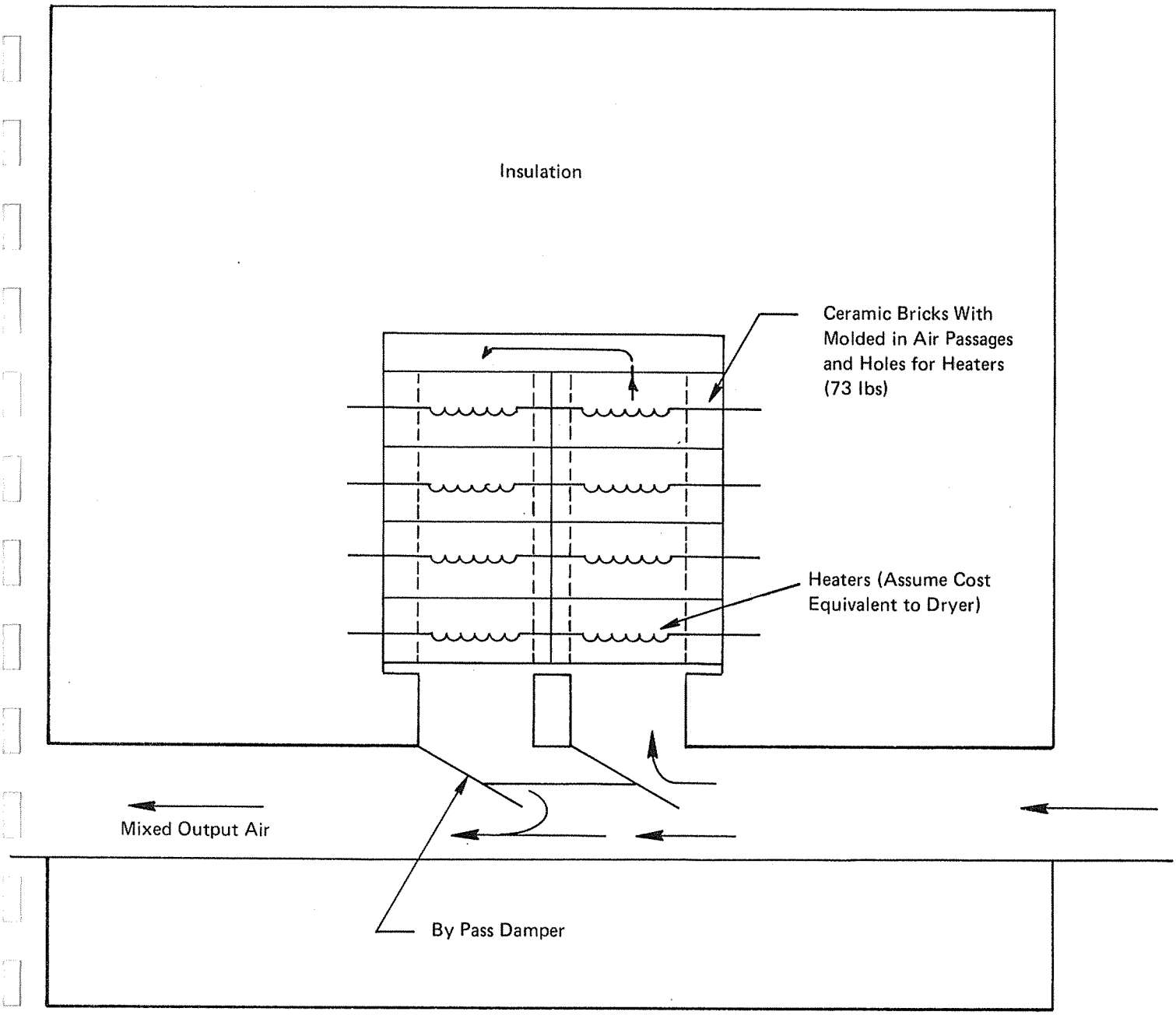


FIGURE 4.1 THERMAL STORAGE MODULE FOR CLOTHES DRYING

Heaters	no charge (replace existing ones)
Bypass & Controls	$15.00
Bricks 73 lbs @ $.06/lb	4.38
Insulation 11 ft^3 @ $5.00 ft^3	55.00
Housing 30 ft^2 @ $.37/$ft^2$ (includes painting)	11.00
Assembly 1/4 hr @ $6.00/hr.	1.50
	$86.88

UTILITY TYPE	SAVINGS ($/yr)	YEARS TO PAYBACK	YEARS TO PAYBACK WITH LOSS OF 360 Kwh @1.4¢/Kwh
Winter Peaking	6.98 (Table 3.1)	12.4	44.8
Summer Peaking	10.80 (Table 3.1)	8.0	15.1

TABLE 4.3 ECONOMICS OF OFF-PEAK THERMAL STORAGE FOR CLOTHES DRYING

contains the same amount of water as clothes (approximately 10 pounds). Silica gel could be used as a desiccant for this purpose. It would require 70 lbs of silica gel to absorb this amount of water in a reasonable time frame.* The solenoid valves are necessary to keep the silica gel dry after it has been regenerated by isolating it from ambient air. When the valves are closed, the pressure in the container will fall as the temperature of the silica gel drops following regeneration at the required temperature of 350°F. Therefore, a pressure vessel is required to contain the silica gel.

This system is shown schematically in Figure 4.2 together with an estimate of its cost. In addition to the items shown, more complicated controls and some external ducting to bypass air flows during regeneration would be required. However, the three major elements already identified cost approximately $200. Given the potential cost savings of $7. to $15. from the use of this device, it is obviously not a commercially viable alternative.

From the consideration of the various possible storage systems for those appliances which use small amounts of energy at infrequent intervals, it appears that no economically viable thermal storage system is available. The cost of the thermal storage system plus the standby losses resulting from the long period of time between charging and using it make these applications economically unattractive. Space heating and water heating applications which utilize energy on a more continuous basis have a much higher potential payback because their energy use is so much greater than that of the smaller appliances.

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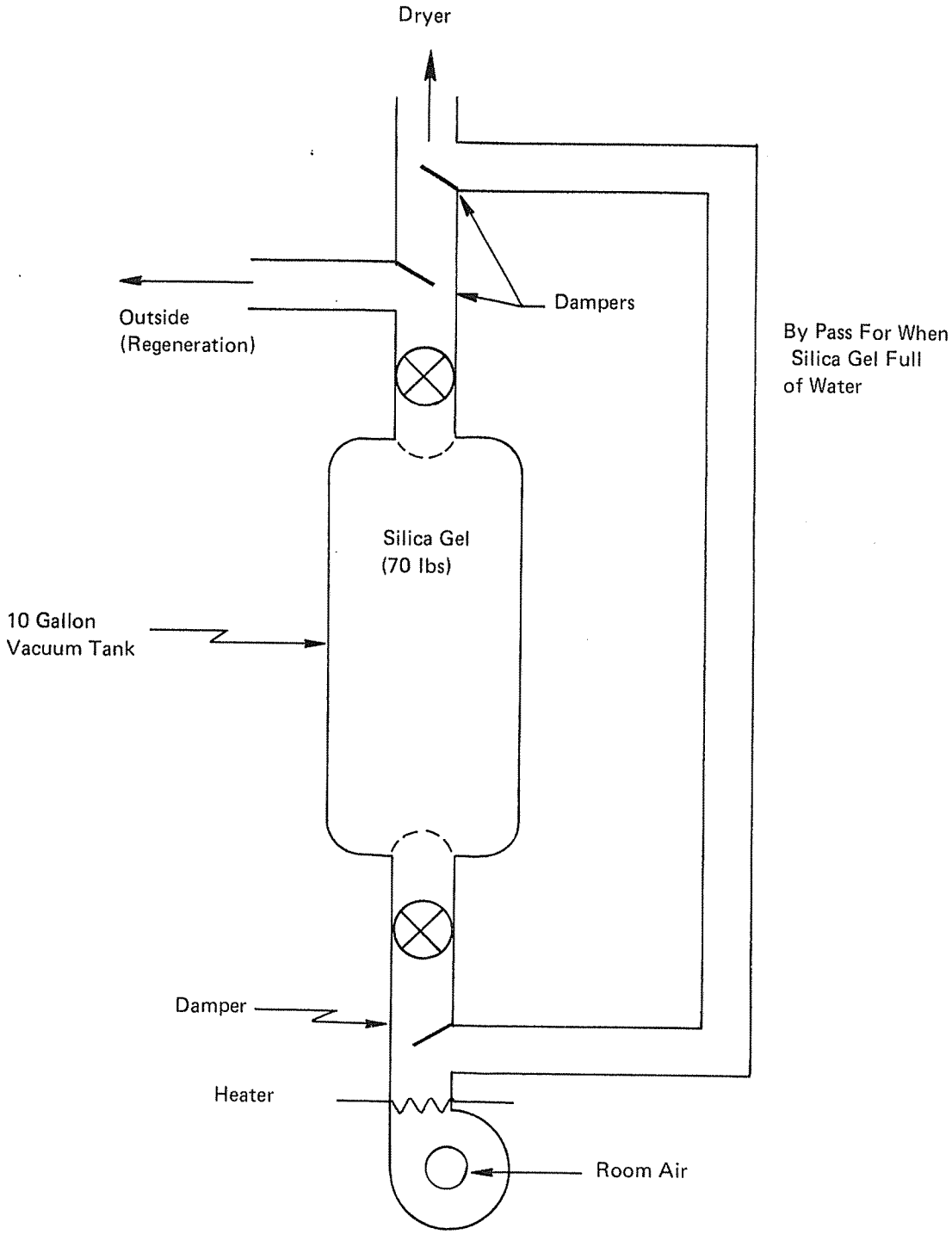
* The drying mechanism of clothes has been investigated by several researchers (Reference 9, AGA) but the use of a desiccant has not been tested and might not work.



Item:		
	Silica Gel (70 lbs @ $ .65/lb)	$ 45.50
	Vacuum Tank (10 Gallon)	20.00
	Valves (2, 1 1/2" Orifice @ $65)	130.00
	Total	$ 195.50

FIGURE 4.2 DESICCANT STORAGE SYSTEM FOR CLOTHES DRYER

4.2.2 Mechanical Storage Systems

4.2.2.1 Introduction

In order to evaluate the potential for shifting motor loads off-peak, various schemes for storing mechanical energy were evaluated. The particular appliances considered were clothes washers, clothes dryers and dishwashers. The systems considered and some of the design factor impacting on them are discussed in the following section. In general, no method for storing this mechanical energy could be identified which could be manufactured at a cost consistent with the cost savings potential related to shifting the loads from these devices off-peak.

4.2.2.2 Energy Storage Requirements

Operating requirements for the appliances discussed in Chapter 2 are shown in Table 4.4. Yearly savings for using off-peak storage to power these appliances were estimated to range between $.87-$2.49/year as shown in Chapter 3.

TABLE 4.4

TYPICAL OPERATING REQUIREMENTS FOR APPLIANCE MOTORS

APPLIANCE	MOTOR (hp)	OPERATING TIME (min)	OPERATING ENERGY REQUIRED		ENERGY STORAGE REQUIRED	
			Wh	ft lb	Wh	ft lb
Washer	1/3	20	81	220,000	243	660,000
Dryer	1/3	40	162	440,000	486	1,320,000
Dishwasher	1/6	30	61	165,000	183	495,000

Since the system must deliver torque as well as energy, additional capacity must be stored to meet the torque requirements at the end of the operating cycle, if the storage system has an output torque which varies with energy storage contents. Therefore, the energy storage requirements have been assumed to be three times the operating requirements. Thus a Mechanical Energy Storage (MES) system must store a minimum of 183 Wh (for dishwashers).

4.2.2.3 Alternate MES Systems

Flywheels store kinetic energy and thus differ from those MES systems which store potential energy. Since energy stored in the flywheel is lost over time, flywheels are most appropriately used for applications where the stored energy can be used shortly after charging. Figure 4.3 shows a possible configuration for a flywheel storage system. Energy is

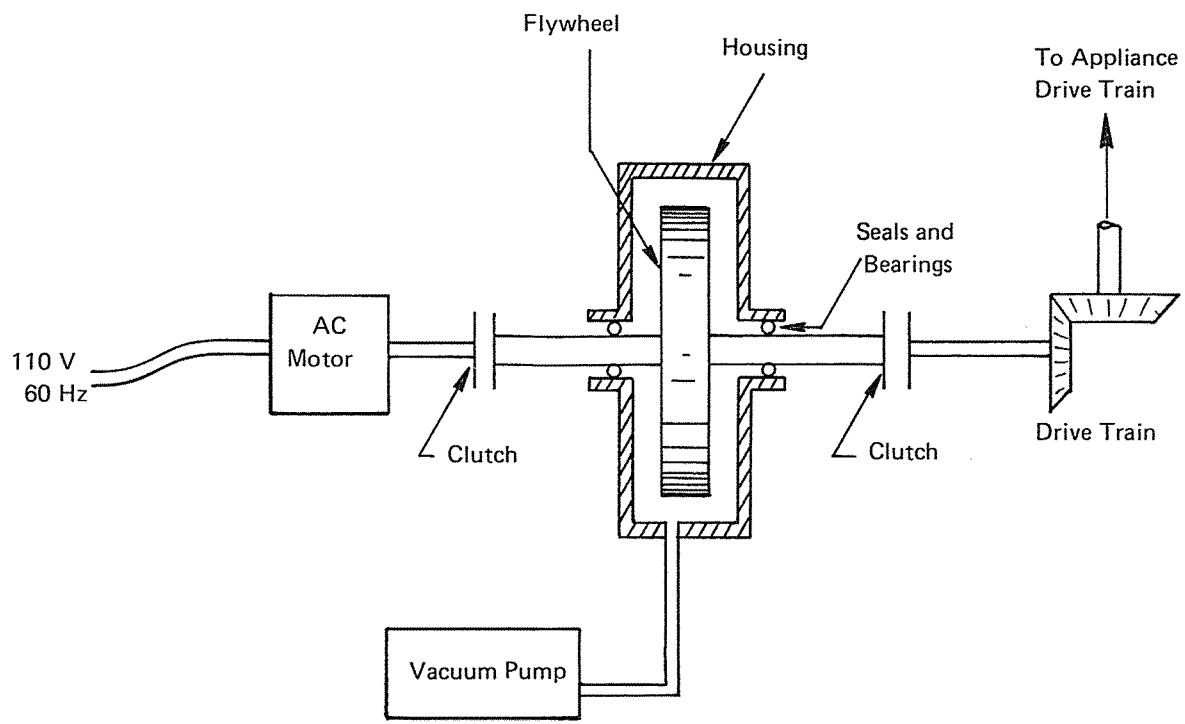


FIGURE 4.3 FLYWHEEL MES CONFIGURATION

dissipated in a flywheel through bearing and seal friction and windage (a function of the air space surrounding the flywheel). Flywheels are contained in sealed housings in which a vacuum is maintained to reduce air resistance and windage losses. The losses in the vacuum pump itself must also be considered in flywheel calculations. Losses also occur in the drive train as energy is transmitted from the flywheel to the appliance. Energy lost from the flywheel typically is 1 to 5% per minute and must be made up by charging the flywheel to maintain its angular velocity. Obviously, flywheels would be impractical for this application since the cost of maintaining the stored energy would exceed the cost savings that could be achieved by off-peak charging and long term power storage without input is not possible.

Compressed Gas is stored potential energy. A possible configuration for a compressed gas storage system is shown in Figure 4.4. A compressor charges the receiver through a one-way valve. The gas is then stored in the receiver until operating the appliance. Air then passes through a control valve and pressure regulator and is heated by a large air-to-air heat exchanger to the air motor. Without this heat exchanger for higher pressures, the cold expanded air would condense and freeze water vapor which would interfere with the operation of the air motor.

The volume and pressure of the gas stored in the receiver determine the stored energy. For example, for a volume of 1 cubic foot of air at 100 psig the stored energy (E_S) can be calculated as follows:

$$E_S = 100 \frac{lb}{in^2} * 1\ ft^3 * 144 \frac{in^2}{ft^2} = 14{,}400\ ft\ lb$$

Requirements for the appliances show that the minimum energy to be stored is 495,000 ft lb. At 100 psig a receiver volume of 33.4 ft^3 (234 gal) would be required which would be an impractical size for use in appliances. If the pressure were increased to 1000 psig, a 3.3 ft^3 (23.4 gal) receiver volume would be required. However, a compressor that could fill the receiver at 1000 psig costs in the range of $1500-2000 in single units and $900-$1200 for an OEM purchase of 10,000 units.

Clearly, the cost of a compressed gas storage system would exceed any possible benefits from the use of the system.

Hydraulic Accumulators are somewhat similar to compressed gas storage systems (See Figure 4.5). The hydraulic accumulator stores energy by compressing a gas contained within a cavity as the working fluid (usually oil) is forced from the reservoir into the accumulator by the pump. To operate the appliance, the oil is released through a hydraulic motor back to the reservoir.

Hydraulic motors operate in the 3,000-5,000 psi range. A combination pump and motor for this application would cost $400-600 in OEM purchases of 10,000 units. The low pressure hydraulic reservoir with a 6 gal volume costs about $40. This system also does not provide a reasonable payback.

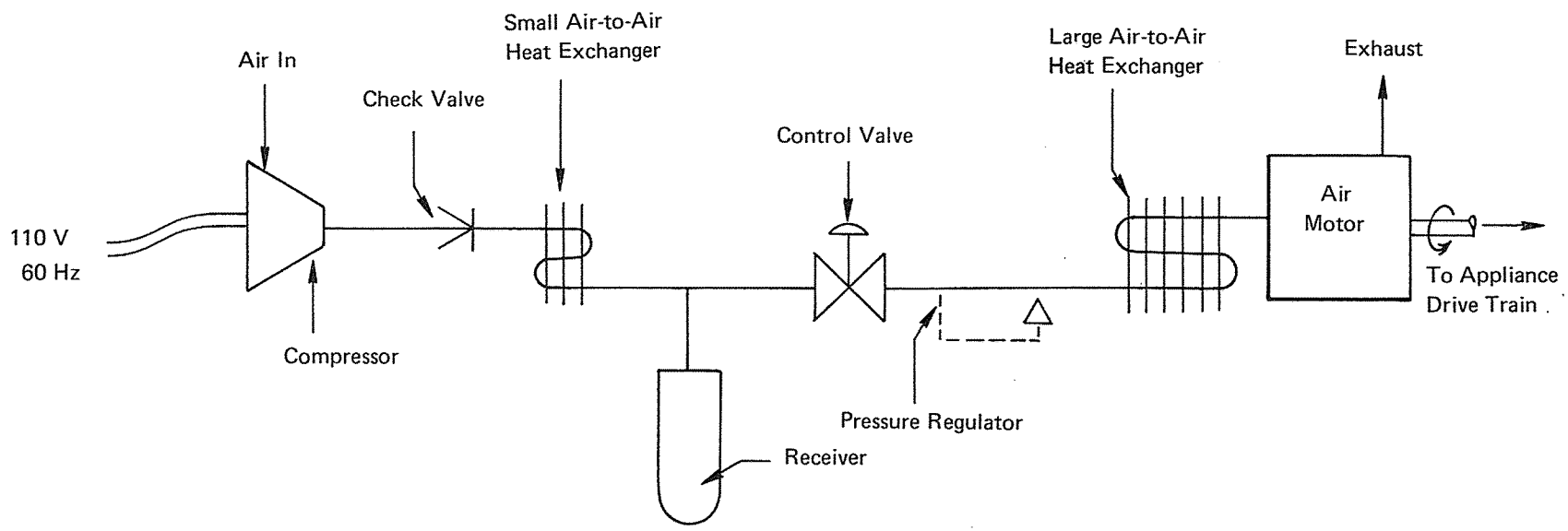


FIGURE 4.4 COMPRESSED GAS STORAGE CONFIGURATION

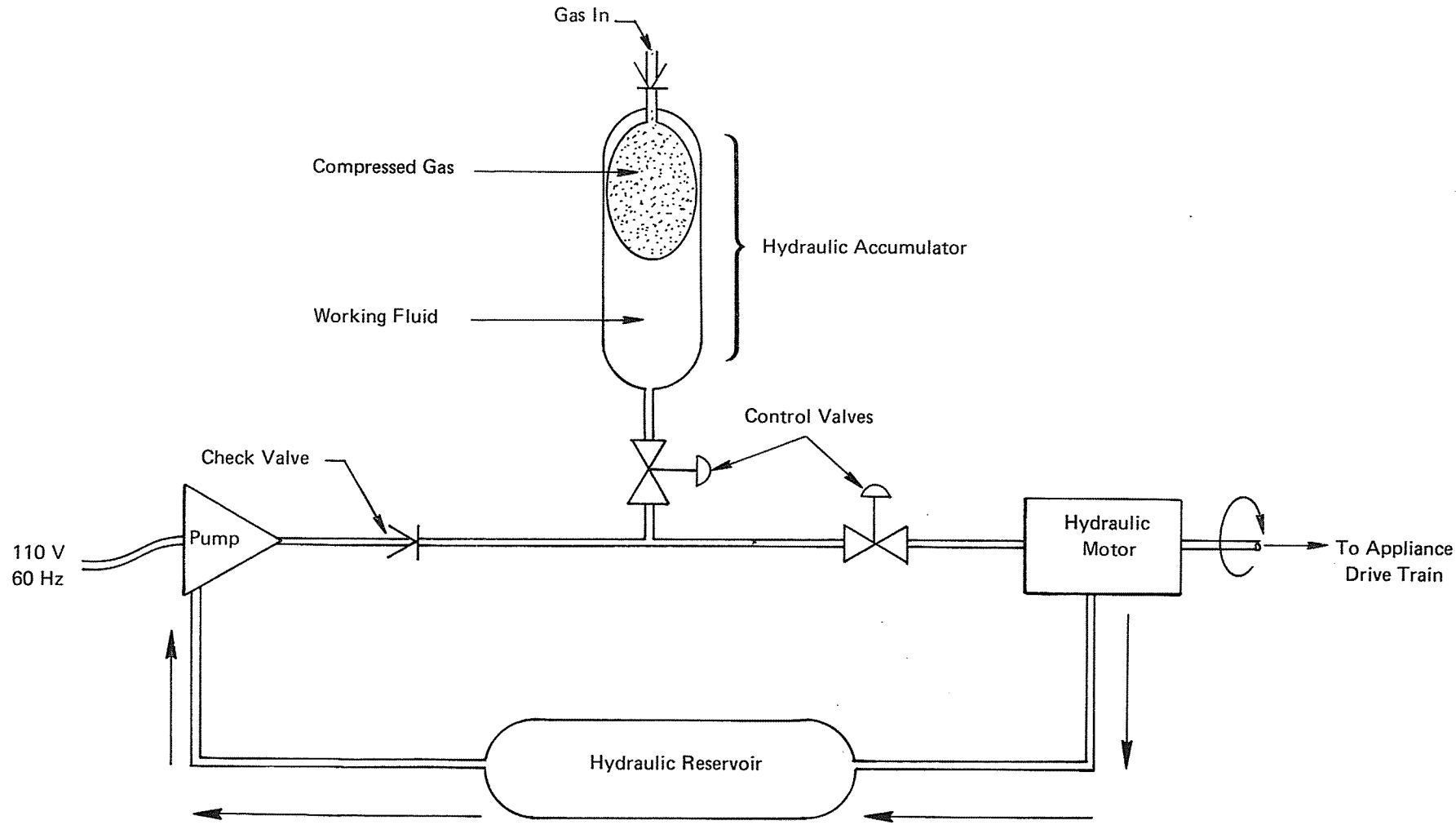


FIGURE 4.5 HYDRAULIC ACCUMULATOR ENERGY STORAGE CONFIGURATION

Springs and Elastomers can be used to store energy. Reference 10 (Kincaid) summarizes the maximum energy stored capability of various materials. Rubber bands can store one Wh/lb of material and springs 0.06 Wh/lb. With a minimum storage requirement of 183 Wh (for dishwashers) approximately 183 lbs of elastomeric material and 3050 lbs of spring material would be required. Reference 11 (Behrin) contains a more detailed analysis of MES systems and includes a consideration of different materials. Polyurethane was shown to have an available energy density of almost 4 Wh/lb which was reduced to under 2 Wh/lb with fatigue following one cycle. However, this gravimetric specific energy only includes the elastomer itself. In this reference, a hydraulic cylinder is described that is driven by an elastomer. The entire system stores 207 Wh of mechanical energy but weighs 309 lbs.

The different materials for springs have capacities that range from 0.73 Wh/lb to 2.81 Wh/lb with cost of material ranging from $0.60/lb to $6.00/lb. Thus, a 183 Wh system costs from $87 to $4816 just for the spring material. Thus this approach also is not economically viable for this application.

4.2.3 Battery Storage

4.2.3.1 Introduction

The cost and efficiency of two types of battery storage systems for operating appliance motors have been evaluated. The first system, as diagrammed in Figure 4.6a, includes a battery and charger and an inverter to allow operation of the ac motor from the battery dc voltage. A switch is included in the system to control whether the motor operates from either the battery or the utility directly. The second system, as diagrammed in 4.6b, includes a dc motor which operates directly from battery voltage. However, to operate the dc motor from the utility, a dc power supply is required. For this analysis, it has been assumed that both systems would use the same capacity battery and charger.

The three appliances evaluated here are: a dishwasher, clothes washer, and clothes dryer. A brief investigation was also made into the costs of components for providing centralized battery storage for a household assuming a requirement of 8.5 Kwh/day.

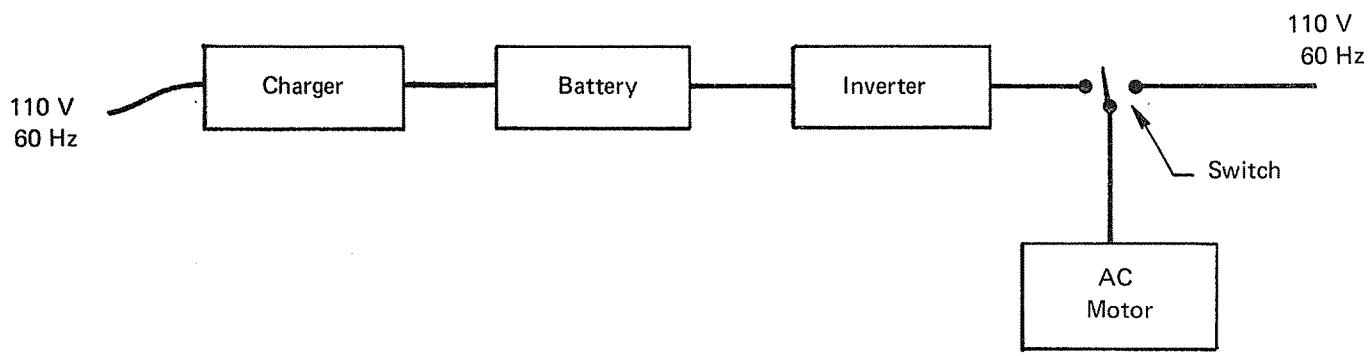
4.2.3.2 Requirements

Typical operating requirements for the three appliance motors are outlined in Table 4.5. The time to discharge a battery ranges from 20-40 minutes, and the total energy needed ranges from 60-160 Wh. All calculations assume that the appliance will be operated a maximum of one cycle per day from the battery.

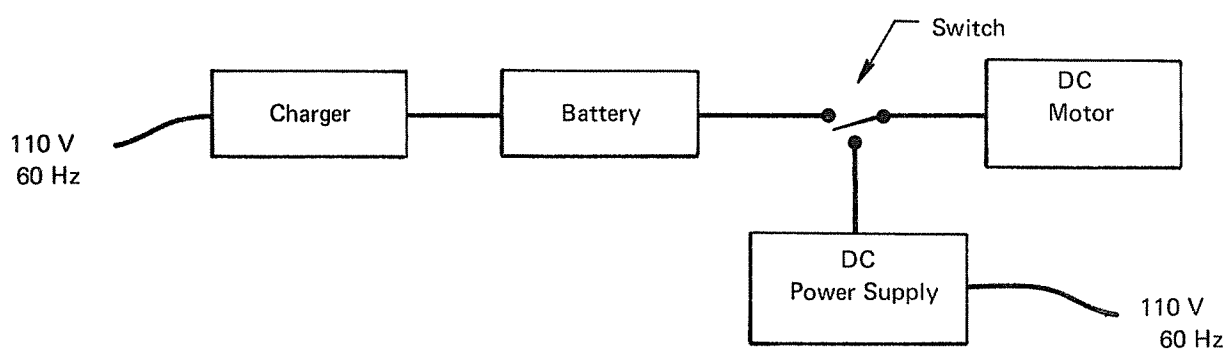
TABLE 4.5

Typical Operating Requirements for Appliance Motors

Appliance	Motor (hp)	Operating Time (min)	Operating Energy (Wh)
Dishwasher	1/6	30	60
Clothes Dryer	1/3	20	80
Clothes Dryer	1/3	40	160



A.



B.

FIGURE 4.6 DIAGRAM OF TWO BATTERY STORAGE SYSTEMS

4.2.3.3 Battery and Charger Costs

The sizes and costs of batteries and chargers are detailed in Table 4.6. These numbers are based on products that can be purchased at this time. The sizes of the batteries are over-specified in some categories (e.g., SLI auto type) because the larger battery is less expensive than one that just meets the requirement. This is due to the large volume market for the larger battery. If sufficient demand could be developed for a battery that just meets the requirement, a less expensive product would be available.

The rapid discharge rate of the batteries, 20-40 minutes, is a stiff requirement. This rate shortens the life of the battery and requires that the batteries have a higher storage capacity than would be needed if the same energy could be delivered over a longer period (e.g., 20 hours).

The "round trip" efficiency of the battery decreases with increasing discharge rate. The battery has an internal resistance that causes energy to be dissipated as heat proportional to the square of the current:

$$P = I^2 R$$

Where P = power dissipated
I = current, and
R = internal resistance of the battery.

As an example for operating the clothes washer 80 Wh are required in 20 minutes. For a 12-volt battery 20 amps will be delivered. In this 20 minute period, assuming a typical internal resistance of 200×10^{-3} ohms:

$$P = (20 \text{ amps})^2 \, (200 \times 10^{-3} \text{ ohms})$$
$$= 80 \text{ watts.}$$

Over the 20 minute period 27 Wh or 33% of the total energy available would be lost as heat, making the battery approximately 67% efficient. The problem of calculating efficiency should be done for each battery in each application and a thorough analysis would require much more than the cursory calculations shown in this example. However, this example does provide a general understanding of the limitations of rapid battery discharge.

Table 4.6 shows that the battery and charger required to store enough energy to allow one cycle of each appliance per day would cost the consumer a minimum of $21 per year for the dishwasher, $30 per year for the clothes washer, and $45 per year for the clothes dryer by using an industrial grade lead-acid battery with a 5-year life. However, the three major disadvantages of the lead-acid battery are (1) during recharging hydrogen gas is produced causing a

TABLE 4.6

SIZE AND COST ANALYSIS OF BATTERIES AND CHARGES BASED UPON STANDARD PRODUCTS NOW AVAILABLE

12V Battery Type (Comment)	Rated*** Capacity (amp hrs)	Battery Cost ($)	Battery*** Life (yr)	Charger Cost ($)	Battery + Charger** Cost per Year ($/year)	Appliance****
LEAD ACID						
SLT (auto type) • very short life under this type of duty cycle	40 40 40	25-30 25-30 25-30	1/6 1/6 1/6	20-25 20-25 20-25	150-180 150-180 150-180	Dishwasher 60 wh C. washer 80 wh C. dryer 160 wh
Golf Cart Battery (6V) • maintenance • hydrogen explosion • acid corrosion	200 200 200	45 45 45	1 1 1	30 30 30	48 48 48	Dishwasher C. washer C. dryer
Industrial • maintenance • hydrogen explosion • acid corrosion	15 25 50	90 130 200	5 5 5	30 40 45	21 30 45	Dishwasher C. washer C. dryer
Sealed • maintenance-free	18 @ 5+ 6 @ 10 12 @ 10	45 (@ 2.50) 80 (@ 13.00) 160 (@ 13.00)	1 1 1	20 30 35	47 83 163	Dishwasher C. washer C. dryer
Nickel/Cadmium Pocket-Plate • maintenance free • long life	10 @ 10 15 @ 10 25 @ 10	400 600 1000	>10 >10 >10	20 30 35	< 42 < 63 < 103	Dishwasher C. washer C. dryer

* Assuming OEM volumes of 10,000 units.

** Assume 10 year life on charger.

*** Assume battery capacity and life based upon 1 charge-discharge cycle per day for each appliance.

**** Typical operating characteristics for appliances outlined in Table 4.5. Anticipated annual savings for off-peak storage: dishwasher $1.00, clotheswasher $0.87, clothes dryer $2.49.

\+ Shorthand notation for 18 batteries in series with a capacity of 5 amp hours each.

potential for explosion; (2) periodic maintenance is required; and (3) leaking acid can cause appliances to corrode.

Golf cart batteries are available in six volt size for slightly greater cost but with all the disadvantages. SLI type lead acid used in autos are the least expensive batteries to purchase but they would last only two months.

For a greater cost, sealed lead-acid batteries can be purchased without the disadvantages of the industrial type. These batteries would last one year under the rapid discharge/slow recharge cycles required for this application. They would cost $47 per year for dishwashers, $83 per year for clothes washers, and $163 per year for clothes dryers, but they are maintenance-free and would not cause acid corrosion. The self-sealing vents used by at least one manufacturer prevent high gas pressures from building up during charging and prevents air from entering the battery during discharge, thus minimizing the risk of explosion.

Pocket-plate nickel cadmium batteries have a high purchase price: $400-1000 but last for at least 10 years without the maintenance and hazards of unsealed lead-acid types. If their cost can be amortized over 10 years, then costs range from $42 to $103 per year for these appliances. A five-year amortization would double these costs.

4.2.3.4 AC Motor system

As shown in Figure 4.6a, a battery storage system using an ac motor also requires an inverter. Inverters convert dc voltage to an alternating voltage. Losses in the ferrite core and the waveform of the output control the efficiency of the inverter. A solid state inverter with a square-wave output typically costs $60 - 70/Kw with an efficiency of 80%. However, not all ac motors can accept a square wave input. Inverters that produce a sine wave output principally use linear amplifers to "round off" the square wave. This results in an efficiency loss so that these operate at 75% and cost $100./Kw. For this application, it is sensible to choose the higher efficiency/lower cost alternative and replace the present ac motor with one that accepts a square wave input as well as a sine wave input. We expect that this change would not increase the motor cost.

An ac motor already available in these appliances costs about $40 for a 1/6 hp dishwasher and $70 for a 1/3 hp for clothes washers and dryers. A matched inverter-motor thus costs from $100-140.

4.2.3.5 DC Motor system

A dc motor can operate from a 12 v battery with no inverter and its associated cost and loss of efficiency. A 12V dc motor costs $150 for a 1/6 hp and $210 for a 1/3 hp size for this application. However, if the battery stores sufficient energy for one cycle, a dc power supply would be required to allow operation from the utility. This power supply would cost $40 for the dishwasher and $60 for the clothes washer and dryer.

The total cost for the dc motor and power supply would be $190-270. Assuming a replacement of the available ac motor, the dc motor/power supply would increase appliance cost by $150-200.

4.2.3.6 Efficiency and Cost

For the battery storage system using the ac motor, efficiencies for each of the components are as follows:

- dishwasher--charger, 95%; battery, 70%; inverter, 80%; for a total of 53%,
- clothes washer and dryer--charger, 95%; battery, 60%; inverter, 80%; for a total of 45%.

The total additional annual costs of these systems assuming the use of a safe, maintenance-free, lead-acid battery and ac motor amortizing the system over 5 years is as follows:

- dishwasher--charger, battery, inverter, and switch - $75 per year,
- clothes washer--$120 per year, and
- clothes dryer--$200 per year.

For the dc motor system, efficiencies and costs would be higher. The efficiencies are as follows:

- dishwasher--charger, 95%; battery, 70%; for a total of 66%,
- clothes washer and dryer--charger, 95%; battery, 60%; for a total of 57%.

The total additional annual costs assuming sealed lead-acid batteries, replacement of ac motor with dc motor, power supply and 5 year amortization are as follows:

- dishwasher--charger, battery dc motor, power supply and demand - $80 per year,
- clothes washer--$130 per year, and
- clothes dryer--$210 per year.

Overall, the costs of the dc motor system are similar to the ac motor system, but the efficiencies for the dc system are higher for each of the appliances. However, when these annual costs are compared to the anticipated annual savings of $0.87-2.49, battery storage is not economically feasible.

4.2.3.7 Televisions

In order to estimate the cost of battery powered televisions, we used the costs of portable units which are commercially available as a guideline. These units are manufactured and sold in reasonable volumes. Although the price might be reduced by larger production, the off-peak control system cost would more than offset the reduction.

Both black and white and color, are available with battery packs and chargers. The batteries provide 3 to 4 hours of operation and are rechargable 300 to 400 times. Cost information (from Sears 1978 catalogue) is summarized below.

Black and White TV

Conventional, 12" diagonal	$78-118
Battery operated, 9" diagonal	128
12" diagonal	148
Batteries	
lead-acid	25
lead-dioxide (recommended)	30

For a 12" diagonal TV, the average cost differential excluding batteries is $50 (148-98). The batteries cost an additional $30 giving a total of $80. These batteries would have to be replaced about once a year while the cost differential could be amortized over 5 or 10 years. A 5-year schedule would give a total cost including battery replacement of $40/year while a 10 year schedule would cost $35/year (ignoring inflation and the discounted value of the money).

Color TV

Conventional, 12" diagonal	$295
Battery operated, 9" diagonal	325
Battery	70

The costs would be $76/year with a 5 year amortization and $73/year with a 10-year amortization. This scheme would mandate operation of the TV from the battery during peak hours with conventional operation during other times. The maximum battery usage per day would be 4 hours.

The use of off-peak power for televisions is difficult to implement since sets can be unplugged. Unless selected outlets are wired especially for off-peak use and a way is found to insure that appropriate appliances are plugged into these outlets, each appliance must be activated from the central station. Although such control devices are available, the cost is prohibitive compared to the savings potential. If a circuit were wired for off-peak appliances, they could be operated by a central time clock and the cost of the controls could be spread over all the appliances even though each appliance had it's own built-in battery system. This complication applies not just to televisions, but to any appliances which are not wired directly into the house electrical system.

4.2.3.8 Centralized Home Battery Storage

As an alternative to the concept of providing battery storage separately for each utility, a centralized home battery storage system was investigated briefly. The appropriate storage capacity of the battery, 8.5 Kwh/day, was determined by totalling the individual requirements for the refrigerator/freezer, lighting, television, and the motor in dishwaters, clothes washers, and clothes dryers plus 1.0 Kwh for reserve storage capacity. Water heater, heaters for clothes dryers, and range/ovens were excluded as they require 220 volts.

A lead-acid battery to meet this need would cost $900. If the utilization of this battery could be controlled automatically by a load-limiting system, or manually by the consumer, the discharge rate of the battery could be low, high efficiency could be maintained, and battery life extended. However, the typical problems with lead-acid batteries--risk of explosion, periodic maintenance, and acid corrosion--are probably sufficient disadvantages to encourage the use of a more expensive battery.

An inverter for such a system typically might cost $500 per Kw. Assuming a peak load of 1/3 of capacity, the inverter would cost approximately $1400. If some compromises could be made in the quality of the output signal, the cost could be lowered to about $900 ($300/Kw). However, certain appliances requiring a "clean" waveform, e.g. television and audio equipment, may not accept this input.

The charger would cost approximately $200. The total system for household might cost between $2000 and $2500 plus installation and control hardware. The potential yearly savings from Table 3.1 for taking these loads off peak would be $23.90 for the representative summer peaking utility and $16.46 for the winter peaking utility.

4.3 Gas Fired Appliances

In this section the practical aspects of utilizing thermal storage to improve the efficiency of gas fired appliances are discussed. In the case of space heating we have considered only gas fired furnaces as these are the most widespread type and are most likely to benefit from storage due to the nature of the losses involved and the relative cleanliness of the exhaust. Schemes with storage are compared to existing alternatives when appopriate.

Table 4.7 shows several different configurations of furnaces. The first case, "Baseline," represents the average of units which are in use today. The second case, titled "State-of-the Art" is representative of gas fired furnaces which are now being manufactured and sold by several different companies. Those units include electronic spark ignition to replace the pilot and flue dampers to prevent standby and intermittent cool-down losses by closing off the flue when the burner is not operating. Table 4.8 shows costs for several different energy saving furnaces which include these features. Although units with pilots are still being sold, Carrier plans to stop manufacturing them by June 1979 because they will not be able to meet the efficiency standards. The pilot type units are already off the market in California.

The third and fourth cases in Table 4.7 are units that are presently "under development" which will give higher recovery efficiencies by using larger heat exchangers to reduce the exhaust temperature to 250°F in the case of 85% recovery efficiency and to 80°F plus recovering heat from the condensing fluid in the case of 90% recovery efficiency. Although these units are not presently available, they are in the process of being developed and several programs aimed at obtaining these efficiencies have been initiated by the Department of Energy, AGA, and industry.

The final category, "Storage to Provide Continuous Operation," shows the losses and efficiency which could be obtained with three different configurations if a furnace includes a storage device so that it can be run continuously throughout the heating season by putting energy into storage which is subsequently removed as needed for space heating during the heating season. The three cases are for a recovery efficiency equivalent to that in use today and for two recovery efficiencies which may be obtained by future units. In this case, the pilot light is not used because the burners are assumed to burn continuously. There are no stand-by draft losses, no intermittent cool-down losses and no transient losses because these losses are all associated with cyclic operation and the unit burns continuously. The storage to permit continuous operation offers a very slight advantage over the state-of-the-art units due to the fact that it does not have transient losses. It should be noted, however, that the sizing of such a unit utilizing storage is really not possible, due to the fact that there are heating load variations from season to season for a building. Thus, if the storage were sized exactly for the

TABLE 4.7

ENERGY USE OF VARIOUS GAS FURNACE CONFIGURATIONS

	Baseline	State-of-the-Art	Under Development		Storage to Provide Continuous Operation		
Steady State Recovery Efficiency (%)	72	80	85	90	80	85	90
Pilot Loss	7*	0	0	0	0	0	0
Standby Draft Loss	3	0	0	0	0	0	0
Transient Loss	1	1	1	1	0	0	0
Intermittent Cool-down Loss	3	0	0	0	0	0	0
Flue Loss	26	15	11	7	15	11	7
Useful Output	60	60	60	60	60	60	60
Total Input	100	76	72	68	75	71	67
Overall Efficiency (%)	60	79	83	88	80	85	90

* Note: Energy use in 10^6 Btu/year/appliance

TABLE 4.8

COST OF "ENERGY SAVING" GAS FURNACES

Manufacturer	Model #	Cost[1] ($)	Vent Damper Cost ($)	Total ($)
Bryant	397E[2]	331	70	401
Carrier	58-ES[2]	392	80	472
Carrier	58-GP[3]	332	-	332

[1]Distributer price to installer.

[2]100,000 Btu/hr output, AGA certified for use with vent damper, electronic spark ignition included in price.

[3]100,000 Btu/hr output, electronic spark ignition only.

worst year, in all other years, the system would have to cycle off and on because the storage would be filled at sometime during the season. Thus, equipment would have to be included in the furnace for cycling it off and on so that the furnace portion of the system would cost the same as the furnaces shown in Table 4.8.

The only losses which could actually be reduced by the storage system would be the transient losses since the number of cycles/year would be significantly lower. However, the maximum saving in transient losses of one million Btu/yr would be more than offset by stand-by losses in the thermal storage unit.

Table 4.9 shows data for different water heaters using gas. The first column shows energy use for the baseline gas fired water heater which is representative of those installed today. Also shown is an estimate of the likely energy consumption for gas water heaters which will be marketed in 1979. The pilot losses are reduced by using a smaller pilot. The jacket losses are reduced by the use of better insulation and plastic fittings to reduce conduction losses through the pipes. The use of baffles in the flue are projected to increase the recovery efficiency to 78% from the present 72%. These all lead to the flue loss as shown and a total energy consumption which is reduced by 6.6 million Btu's per year.

Storage would be utilized in this case to make it possible to remove the pilot loss and the stand-by draft losses by using a large enough water tank so that a smaller burner could run continuously. This increase in size, using the same insulation, would result in an increase in jacket losses. For the case shown a 120 gallon tank was assumed to replace a 40 gallon tank to provide the additional storage capacity. This results in an increase in surface area of approximately 2 1/2 times the initial surface area assuming that the 120 gallon tank is twice the height of the 40 gallon tank with the remainder of the volume increase being made up by utilizing a larger diameter. This would still result in a lower overall energy consumption. However, practical implementation of the system has the same difficulty as that mentioned above for space heating. Water usage is not constant on a daily or weekly basis. For example, on weekends significantly less water may be used than during the week depending on factors such as variations in the number of washer loads per week, families going away on week ends and vacations, summer washing habits differing from winter ones, etc. Thus, the system must be able to meet the demands of the worst use period which means that at other times the system will be filled and the burner will have to be turned off and on. Thus, the unit would have to include a pilot. However, the larger storage size would result in shorter periods when only the pilot was operating. Assuming that this configuration reduced the "off" time by 95% from that with present tank sizes, an energy savings of 1.8×10^6 Btu/yr would result. At \$3.50/10^6 Btu, this would save \$6.30/yr The additional storage would cost at least \$2/gallon or \$160 giving a years to pay back of 25.4. Clearly this is too large to be economically attractive.

TABLE 4.9

ENERGY USE OF VARIOUS GAS WATER HEATER CONFIGURATIONS

	Baseline	1979 Units		120 Gallon Storage Continuous Operation	Practical Limit, 95% on time
		Energy Use	Design Change		
Pilot Loss	5.5*	41	Smaller Pilot	0	0.2
Standby Draft Losses	2.0	2.0	-	0	0.1
Jacket Loss	4.5	2.3	Better Insulation Plastic Fittings	5.8	5.8
Flue Loss (72% for Baseline)	9.3	6.3	78% Recovery	6.7	6.8
Useful Energy	18.0	18.0	-	18.0	18.0
Total Consumption	39.3	32.7		30.5	30.9

* Note: All energy consumption in 10^6 Btu/yr/appliance

In the case of clothes dryers, the units presently in the field are not equipped with a pilot. The only loss is due to the recovery efficiency of the system. Gas ranges presently use a pilot, however, pilotless units are now being marketed which will replace the pilot type in the next few years. In these cases no reasonable storage system to reduce these losses could be developed.

4.4 Refrigeration Cycle Appliances

4.4.1 Introduction

Refrigeration cycle appliances have been treated as a separate category in this program because there is a potential to increase their efficiency by the use of storage and also to shift their loads off-peak thereby saving oil and gas at the utility. The following analyses concentrate on central air conditioners and heat pumps. Refrigerators have been analyzed in a previous Arthur D. Little study (Reference 19: DOE-Refrigerator) for the Department of Energy. In this study we examined the possibility of energy savings through the use of thermal storage in domestic refrigerators. It was thought that by operating the refrigerator during the cooler evening hours, an energy savings could be achieved from reduced condenser temperatures. A maximum savings of approximately 2% was estimated with a likely payback period of greater than 48 years. An additional savings of a maximum of $10 per year from peak electric pricing could be realized as shown in Table 3.1. This would lower the straight line years to payback to approximately 1 to 2 years. However, the 2% savings is small in relation to total U.S. energy consumption when compared to efficiency improvements in refrigerators which can be obtained from other approaches.

A high pressure liquid accumulator system is a type of energy storage system that may provide some energy savings. The liquid accumulator could be used in conjunction with improved expansion devices to optimize the system performance. The present capillary tube system is designed to provide optimum operation in a narrow range of operating conditions. A liquid accumulator and improved expansion device may extend the optimum operation range and permit more cost effective unit design. Because of the complexity of this type of energy storage, considerable experimental work is needed before the energy savings of a liquid accumulator can be assessed.

Room air conditioners were not considered as a separate category because, at best, the energy savings of room air conditioners will be that of the central air conditioner. Assuming that three separate room air conditioner units are used in the same building, the cost will be considerably greater to implement the energy storage since these units are to be interconnected with costly plumbing and control devices.

In the following sections some specific designs are evaluated and the energy savings potential estimated. None of these designs produced energy savings of sufficient magnitude to offset the added cost of storage with a reasonable pay back period. In fact, some resulted in a higher energy use due to the loss of efficiency associated with the lower evaporator temperatures required to charge the storage system.

4.4.2 Baseline Air Conditioner Energy Consumption

The baseline cooling case described in Appendix F uses a 3 ton unit with approximately 1200 hours run time over a 152 day period. This 33% run time is shown to correspond to a mean temperature of 85°F. Average nightime and daytime temperatures of 80°F and 90°F respectively give duty cycles of 0.15 and 0.50 from Figure F.10 or an average run time of approximately 1200 hours.* These temperatures lead to the energy consumption shown in Table 4.10 using the equations given in Appendix F.

In addition, there are cycling losses estimated as follows:**

	Duty	EER cyclic/EER steady	Kwh loss per day	Annual Kwh loss
Night	0.15	0.70	2.02	307
Day	0.50	0.90	0.55	84

* National average use time, see Reference 1 (Integrated Appliances)

** Based on Reference 12 (Kelley)

TABLE 4.10

BASELINE AIR CONDITIONER ENERGY CONSUMPTION

	Run Time (hr)	Duty	Outdoor Temp (°F)	Condenser* Temp (°F)	Evaporator Temp (°F)	Cooling Rate (Btu/hr)	Input (watt)	Daily Input (Kwh/day)	Daily Total Cooling (Btu/day)
Night	1.8	0.15	80	117	45	38,566	4,741	8.53	69400
Day	6.0	0.50	90	127	45	37,625	4,997	29.98	225800
TOTAL	7.8							38.51	295200

*Assumes a 37°F temperature difference between refrigerant and air temperature.

4.4.3 Air Conditioner with Diurnal Storage Coupled to Heat Exchanger in Duct

This system is shown schematically in Figure 4.7. The evaporator and thermal storage form an integral unit which is positioned directly in the air duct to minimize temperature differences. The improvement in efficiency results from charging storage at night when outdoor temperatures are lower. It operates as follows:

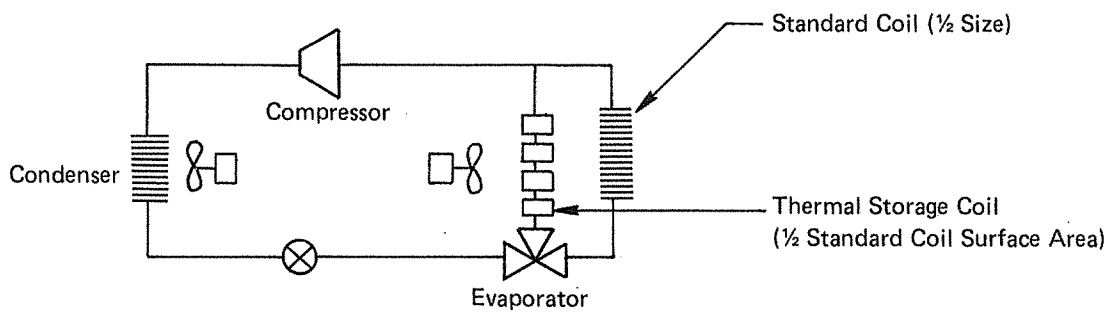


FIGURE 4.7 AIR CONDITIONER WITH STORAGE COIL IN DUCT

- Evening Hours Operation

When cooling is needed, refrigerant is supplied to both coils at 45°F. The thermal storage coil and 1/2 size standard coil cool the air stream.

When charging the thermal storage, the evaporator fan is not run and all the refrigerant goes through the thermal storage. During both of these operations the condensor fan and compressor are run at full speed.

- Daytime Operation

When cooling is needed, the compressor is run at 1/2 speed supplying refrigerant to the standard coil while the remainder of the cooling is provided by discharging the thermal storage. The daily energy consumption for these conditions is given in Table 4.11.

The estimated effect on the steady state energy consumption assuming 6 hours of daytime compressor operation is shown in Table 4.12. This consumption leads to a savings of:

- 2.43 Kwh per day
- 373 Kwh per year
- $14.92/year @ $.04/Kwh
- $95.51/year due to off-peak storage from Table 3.1
- $110.43/year total.

TABLE 4.11

ENERGY USE FOR AIRCONDITIONER WITH STORAGE COIL IN DUCT

	Temperatures (°F) T_e	T_c	OPERATING CONDITIONS (watts) Condenser Fan	Evaporator Fan	Compressor	Total	Refrigeration Q Btu/hr	EER
Nighttime								
Charge								
Storage	45	117	250	0	4241	4491	38566	8.586
Cooling	45	117	250	250	4241	4741	38566	8.134
Daytime								
Cooling from								
Compressor	45	108*	250	250	2005	2505	19706	7.865
Storage	45	---	---		---	---	17919	
TOTAL							37625	

*1/2 speed compressor results in 1/2 the thermal load on the condenser and 1/2 the ΔT condenser to air.

Nomenclature: T_e = refrigerant evaporator temperature

T_c = refrigerant condenser temperature

TABLE 4.12

ENERGY CONSUMPTION WITH STORAGE COIL IN DUCT

	Running Hours	Kw With Storage	Kw Baseline	Kwh With Storage	Kwh Baseline
Nighttime					
Cooling	1.8	4.741	4.741	8.534	8.534
Storage	2.78	4.491	-	12.519	
Daytime					
Cooling	6.0	2.505	4.997	15.03	29.982
TOTAL				36.08	38.516

- Storage Configuration

A thermal storage system for use in this application must permit heat transfer from the refrigerant to the thermal storage media, the refrigerant to air, and from thermal storage to air. The module shown in Figure 4.8 could be used.

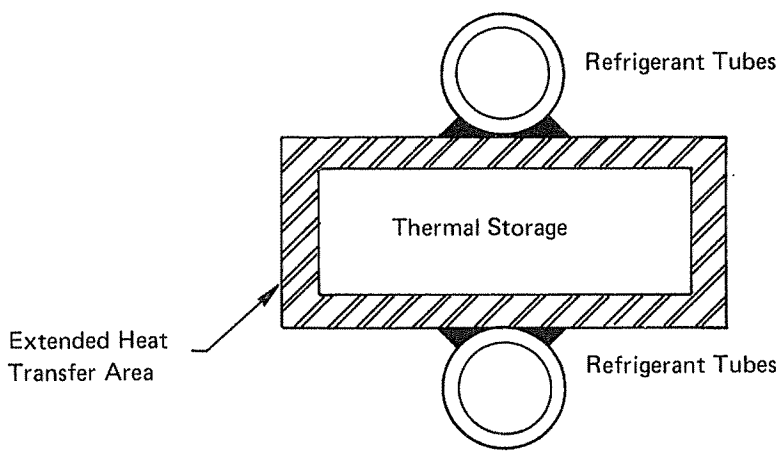


FIGURE 4.8 STORAGE COIL CROSS-SECTION

The extended heat transfer surface area serves both the thermal storage media and the refrigerant tubes when the evaporator fan is on. Without the evaporator fan the major conductance path is between the refrigerant tube and thermal storage.

This system would require the storage of 108,000 Btu. Using water as the storage medium and a temperature range of 35°F to 55°F gives a required volume of 650 gallons. In order to provide an order of magnitude estimate of the cost of this system we calculated that 1000 ft. of 4 inch diameter steel pipe at $2.80/ft. would be required. Clearly this system cannot be practically implemented.

4.4.4 Air Conditioner with Storage External to System

An alternative to the system discussed in Section 4.4.3 employs a single tank external to the system with a heat exchanger to charge and discharge the system (see Figure 4.9). This avoids the large thermal storage unit in the duct but introduces an additional operating penalty due to the temperature differential across the heat exchanger. Energy savings in this case would result from operating the compressor at night when outdoor temperatures are lower. In addition, the device could utilize off peak power. Tables 4.13 and 4.14 show the energy consumption associated with this system.

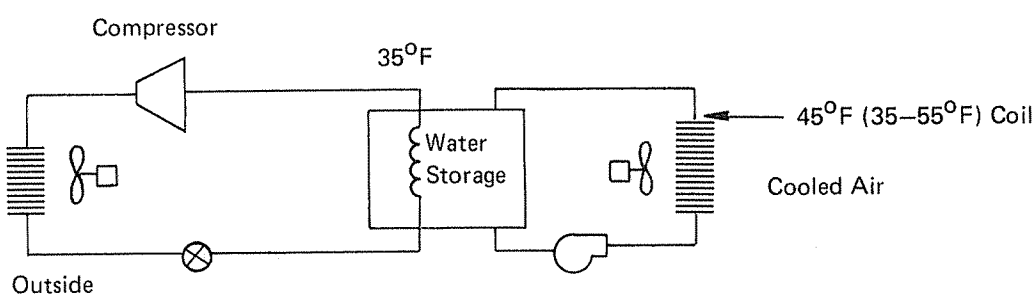


FIGURE 4.9 AIR CONDITIONER WITH EXTERNAL STORAGE

TABLE 4.13

OPERATING CONDITIONS FOR REMOTE STORAGE

	Temperatures		Watts				Refrigeration	
	T_c	T_e	Compressor	Condenser Fan	Evaporator Fan	Total	Q Btu/hour	EER
Evening								
Thermal Storage								
charge	117	35*	3,919	250	0	4169	30701	7.364
cooling	117	35	3,919	250	250	4419	30701	6.947
Daytime								
Thermal Storage								
discharge	---	--	--	--	250	250	37625	--

*10°F difference in the evaporator temperature and the final 45°F air coil temperature.

TABLE 4.14

DAILY ENERGY CONSUMPTION WITH REMOTE STORAGE

	Hours	Kw	Kwh
Evening			
Cooling	2.26	4.419	9.99
Charge	7.35	4.169	30.65
Daytime			
Discharge	6.0	.250	1.50
Daily Total			42.15 Kwh/day

This compares to 38.52 Kwh/day for the baseline system for a loss in performance of 3.63 Kwh/day. Since the unit runs continuously to charge storage, cyclic loss savings of 2.3 Kwh/day will partially offset this steady state loss. However, this still gives a net loss of:

- 1.33 Kwh/day
- 202 Kwh/year
- $8/year @ $.04/Kwh

If a water-glycol mixture cycling through a temperature range of 35°F - 55°F were used as the storage medium in this case, 1800 gallons would be required. An unlined unpressurized tank of this size would cost $1400. The heat exchanger, circulating pump, and insulation would add another $300 giving an approximate cost of $1700. The potential savings for off peak storage of $95/year from Table 3.1 reduced by the $8/year loss above gives a years to pay back for this system of approximately 20 years.

4.4.5 Air Conditioner with Ice Storage for Off Peak Use

The above analysis shows a sensitivity of storage system operating cost to storage temperature. Currently, A.O. Smith, Carrier, and others are developing ice storage units which operate like the system described above but utilize ice as the storage medium. Estimating the energy requirements following the same method used above but using an evaporator temperature of 20°F gives:

- Operating input 59.55 Kwh/day
- Baseline 38.52 Kwh/day
- Operating loss/day 21.03 Kwh/day
- Operating loss/year 3200 Kwh/year
- Cost of loss $120/year @ $.04/Kwh

4.4.6 Air Conditioner with Thermal Storage Subcooler

An integral thermal storage is chilled during off-cycle periods to be used during the cooling cycle to obtain increased condenser subcooling (see Figure 4.10).

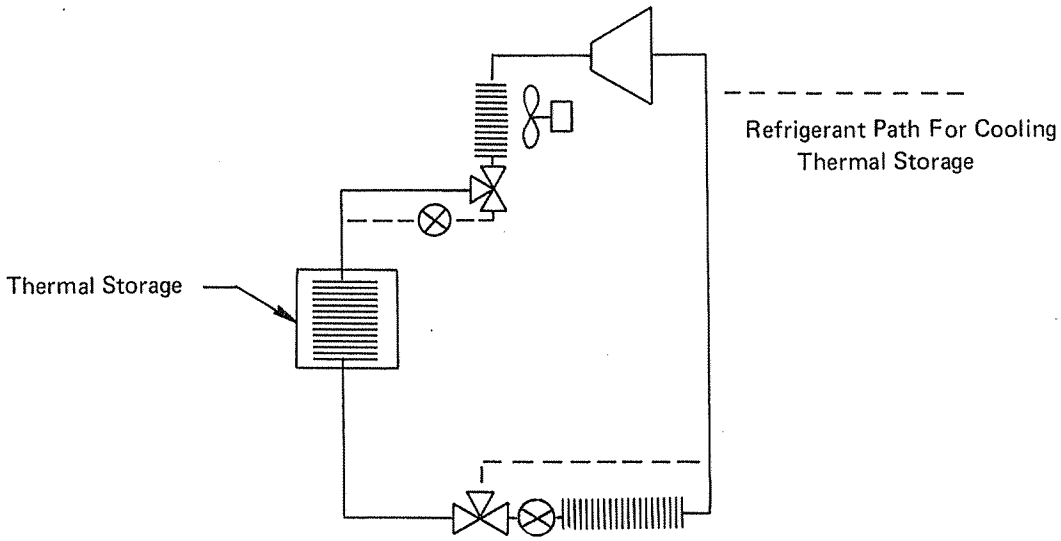


FIGURE 4.10 AIR CONDITIONER WITH THERMAL STORAGE SUBCOOLER

The pre-cooled thermal storage lowers the condensed liquid temperature (subcooled). For a 45°F evaporator and a 120°F condenser with a standard 10°F of subcooling, the effect of lower subcooling temperatures is given below:

$T_{subcooling}$ (°F)	% EER Increase
120	Baseline
100	10.2
80	20.0
60	29.5

On the average:

- Fvery 1°F subcooling improves the EER .5%
- Every 1°F subcooling requires about .3144 Btu of cooling per lb of refrigerant
- Every lb of refrigerant delivers about 70 Btu/lb of cooling at a 45°F evaporator temperature.

Therefore:

$$1^{o}F \text{ subcooling requires } \frac{53.89 \text{ Btu of additional subcooling}}{\text{ton-hour cooling}}$$

or

$$1\% \text{ increase in EER requires } \frac{108 \text{ Btu of additional subcooling}}{\text{ton-hour cooling}}$$

This 108 Btu of additional subcooling will be accomplished by running the refrigeration unit during the off cycle. The amount of off cycle refrigeration is:

$$53.89 \quad (120 - T_{subcooling}) \frac{\text{Btu}}{\text{ton-hour cooling}}$$

and this will require energy.

$$\text{Off cycle energy} = \frac{53.89\ (120 - T_{subcooling})}{EER_2}$$

where EER_2 is the EER while charging storage.

During the on cycle, the following savings is obtained:

$$\underbrace{\left[\frac{\overbrace{(120 - T_{subcooling})(.005)}^{\%\ \text{EER improvement}}}{1 + (120 - T_{subcooling})(.005)}\right]}_{\%\ \text{Energy Savings}^{*}} \frac{\overbrace{12{,}000 \frac{\text{Btu}}{\text{ton-hour}}}^{\text{Standard Power per ton-hour}}}{EER_1} = \text{on cycle energy savings.}$$

where EER_1 is the on-cycle EER.

The net savings is the difference between the off cycle cooling cost and on cycle savings:

---

*energy savings = cooling requirement $\left[\frac{\%\ \text{EER improvement}}{1 + \%\ \text{EER improvement}}\right]$

$$\text{Net savings} = \frac{60\ (120 - T_{sub})}{(1.6 - .005\ T_{sub})\ EER_1} - \frac{53.89\ (120 - T_{sub})}{EER_2}\ \frac{\text{watts-hrs}}{\text{ton-hr cooling}}$$

$$= (120 - T_{sub}) \left[\frac{60}{(1.6 - .005\ T_{sub})\ EER_1} - \frac{53.89}{EER_2} \right]$$

This net savings is shown in Figure 4.11.

This shows that an optimum occurs at about 97°F subcooling. We have assumed that in order to achieve the subcooling temperature the thermal storage temperature is $T_{subcooling}$ - 10°F = 87°F and that to cool the thermal storage, the evaporator is run at $T_{subcooling}$ - 20°F = 77°F.

There is about a 36-37 watt-hour savings per ton-hour of cooling. For the baseline case of 3740 ton-hours/year this is equivalent to a $5.50 savings/year at $.04/Kwh.

The thermal storage unit must handle:

$$\frac{(120-97)\ 53.89\ \text{Btu}}{\text{ton-hour cooling}} = \frac{1239\ \text{Btu}}{\text{ton-hour cooling}} .$$

This may be done on a cycle-to-cycle basis or on a diurnal basis. On a cycle-to-cycle basis for an average 3-ton unit running continuously for about 57 minutes each hour with 3 minutes off, about 3700 Btu of storage at about 87°F may be needed during high run times.

No storage system for this amount of energy which could operate within this temperature range could be identified. A phase change system would be required due to the small temperature differential.

4.4.7 Recondenser

The recondenser was developed by Altman* (see Figure 4.12). It can reduce demand by storing energy at night or with smaller storage it has been proposed as an energy saving system. In operation, during the off cycle, the compressor cools a thermal storage device to about 60°F. When cooling is required, the compressor is operated at conventional evaporator temperatures, and the refrigerant is initially expanded to about 60°F. It then passes through the thermal storage unit where it is recondensed. Finally, it expands into a second evaporator at 40°F doing additional cooling.

*Reference 8 (Altman)

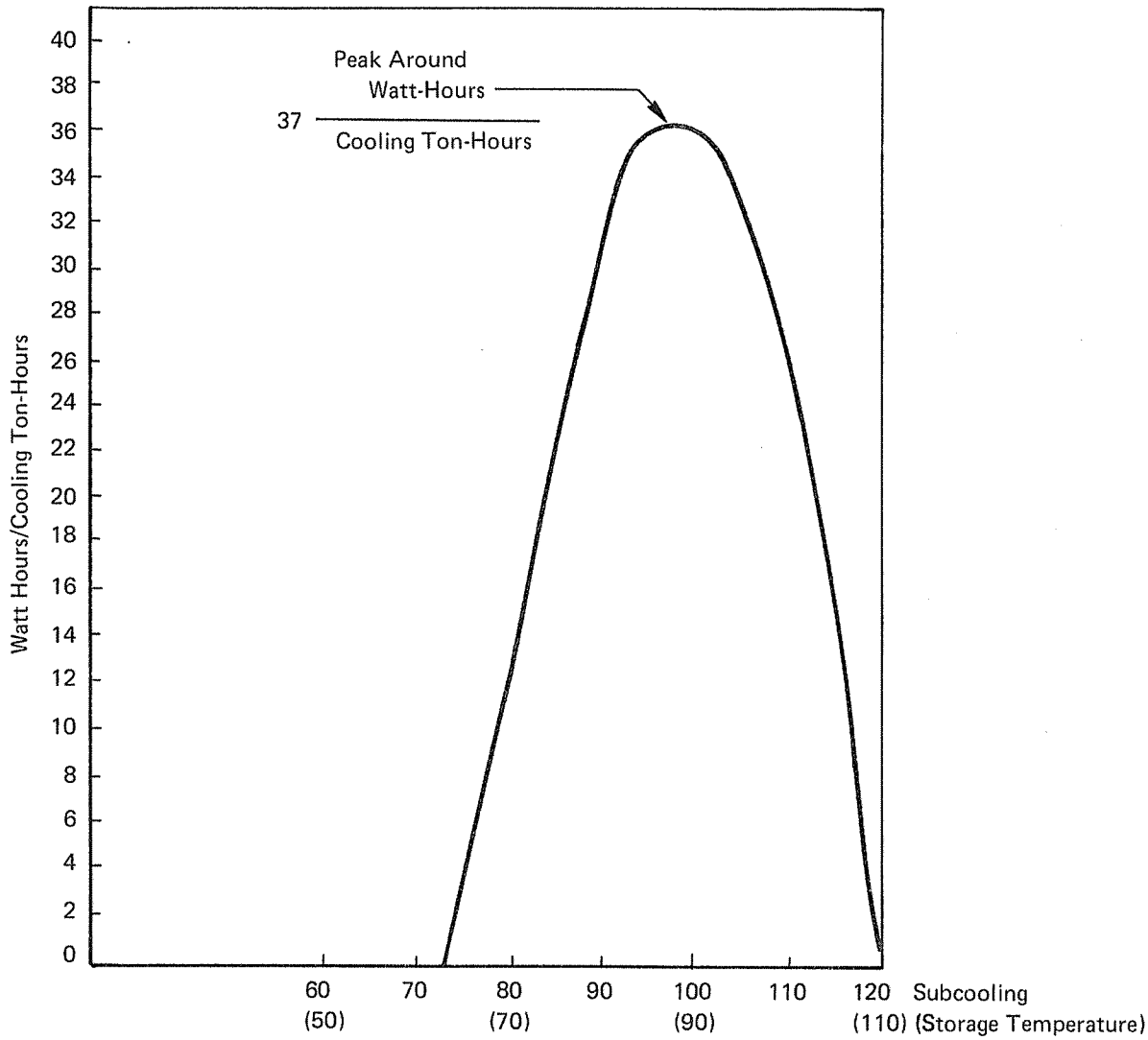


FIGURE 4.11 SAVINGS WITH SUBCOOLING AS A FUNCTION OF TEMPERATURE

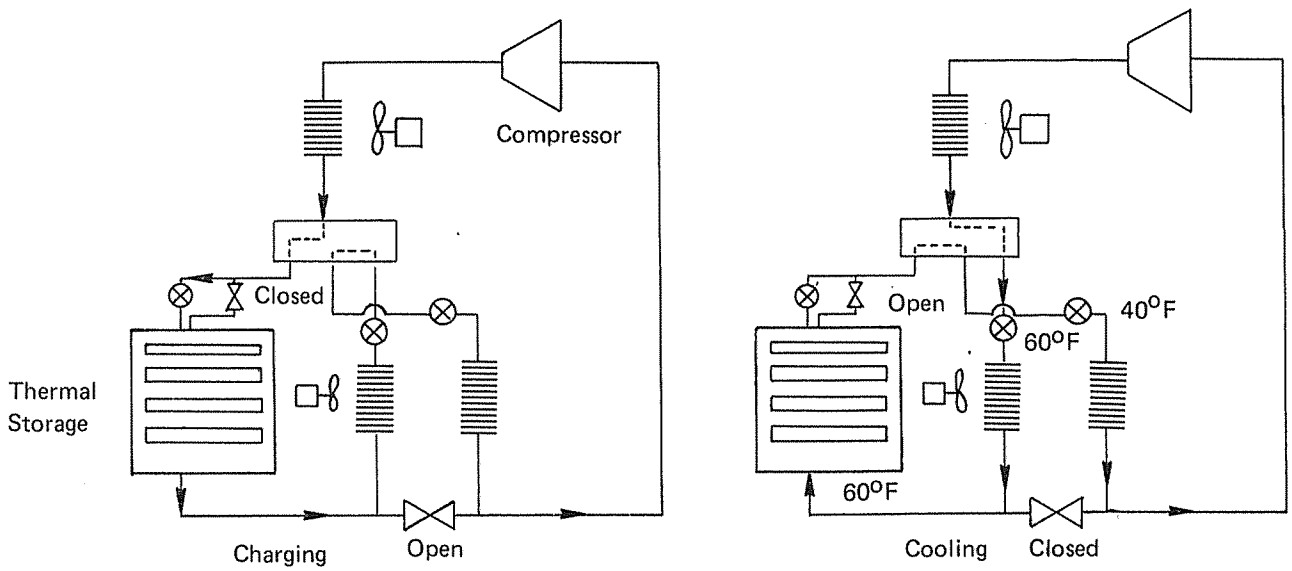
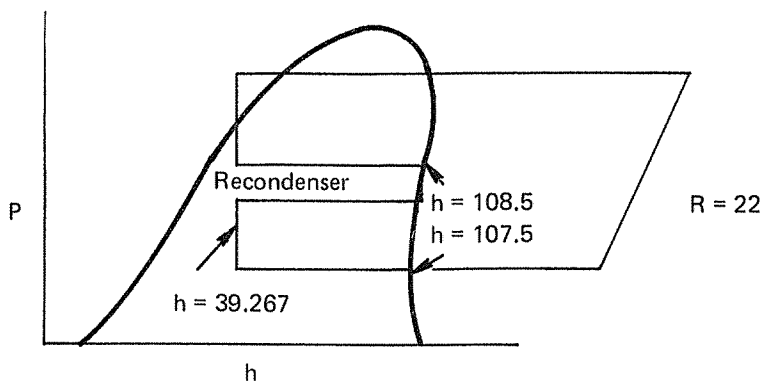


FIGURE 4.12 THERMAL STORAGE RECONDENSER

During the day, the required cooling is accomplished by a reduced refrigerant mass flow rate as seen in the P-h diagram below:



The recondenser increases the refrigeration effect of each pound of refrigerant reducing the mass flow required to approximately half that of the baseline case

In analyzing this system the baseline system must be carefully chosen because the recondenser involves considerable changes.

The recondenser is governed by the following equations for the flow configuration shown in Figure 4.13.

$$\frac{75 - T_{air}}{15} = 1 - e^{-x_1}$$

$$\frac{T_{air} - 45}{T_{air} - 40} = 1 - e^{-x_2}$$

where

$$x_1 + x_2 = \text{NTU}$$

$$= \text{total evaporator NTU}$$

The solution to this equation is shown graphically in Figure 4.14. The design point was selected as it gave the largest first-stage cooling at a reasonable total heat transfer (NTU = 3).

In order to compare the energy consumption of this system with an equivalent baseline, the evaporator of the baseline should be increased to the size of the recondenser evaporator. This results in a new baseline evaporator temperature of T_e = 43.42°F instead of 40°F which gives the following:

	T_e	T_c	Q Btu/hr	E	EER
Original Baseline (NTU = 1.945)	40	127	33693	4808	7.00
Modified Baseline (NTU = 3)	43.42	127	36383	4938	7.36

Thus, using the same size evaporator with the baseline unit raises its efficiency by 5%.

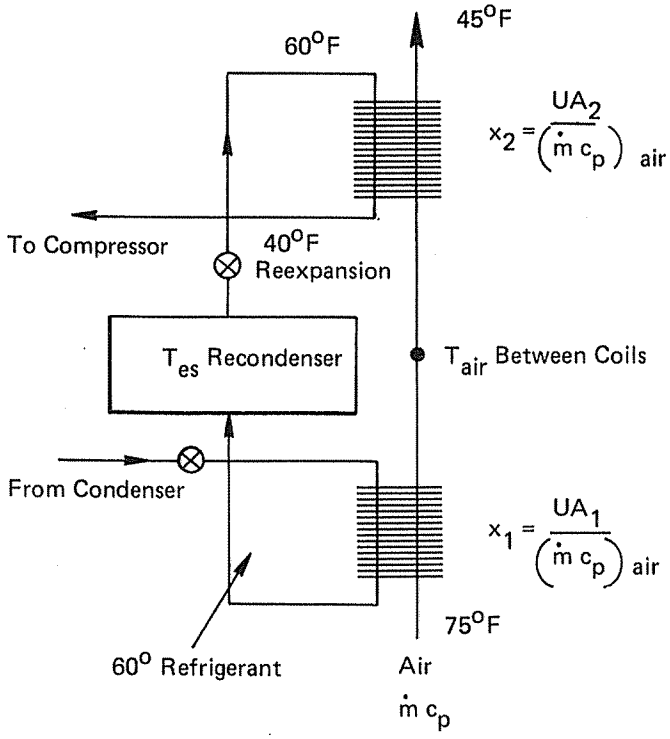


FIGURE 4.13 NOMENCLATURE FOR RECONDENSER HEAT EXCHANGER ANALYSIS

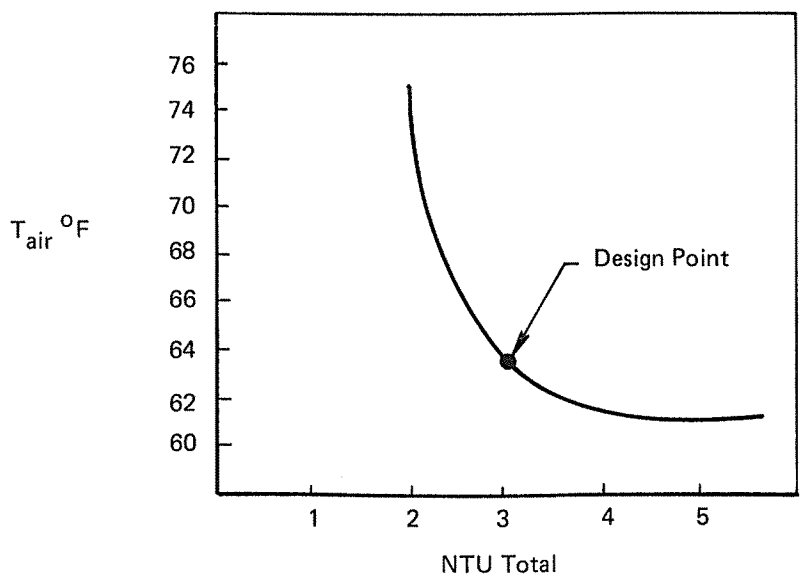


FIGURE 4.14 RECONDENSER HEAT EXCHANGER AIR SELECTION

In order to estimate the energy consumption of the recondenser system when used to provide diurnal storage, we assumed a constant temperature (latent heat type) storage system as this would give the best performance capability. The actual storage temperatures and the evaporator temperatures during charging and discharge of the unit depend on the thermal storage unit heat exchanger surface area. These temperatures can be calculated as follows:

During charging the heat flux is given by:

$$(T_S - T_R)\ UA = \alpha_1 T_R + \beta_1$$

During discharging (1/2 speed compressor)

$$(T_R - T_S)\ UA = 1/2\ (\alpha_2 T_e + \beta_2)$$

Where

T_S = storage temperature

T_R = refrigerant temperature in recondenser

T_e = refrigerant temperature entering compressor

UA = heat exchanger properties

α_1 = 786.5)
β_1 = 2197) from Appendix F

α_2 = 810)
β_2 = 2285) characteristics of cycle shown

Solving these equations for different UA's gives the results shown in Table 4.15. The system with the larger heat exchanger used in the Altman design saves 0.8% of the energy use when compared to the original baseline. However, based on the comparison with the modified baseline, it is not effective in reducing energy consumption, as increasing the evaporator size gives a 4% loss in efficiency. The unit with a smaller heat exchanger area provides poorer performance than both baseline cases. This loss gives the following economics:

- Loss: 231 Kwh/yr
- Cost: $9.24/yr
- Off-Peak Credit (1/2 of Table 3.1 value): $47.76/yr
- Net Savings Potential: $38.52/yr

This system would require the storage of 60,000 Btu at a temperature of 60°F. Because of the narrow temperature range, a phase change storage system is required. A representative cost* for this type system is $6000/million Btu which gives a storage system cost of $3600.

*Based on work in progress.

Constant Temperature Storage

		Hours	Q Btu/hr	T_c(°F)	T_e(°F)	Power (Watts) Com-pressor	Cond.	Evap.	Total	Daily Energy Comsumption (kwh/day)
UA = 1764 T_s = 50.2°F	Cooling	7.8	33693	127	40	2154	125	250	2529	19.72
	Charging	4.7	28896	127	33.9	4077	250	-	4327	20.34
	TOTAL									40.06
UA = 2850 (Altman) T_s = 53.9°F	Cooling	7.8	33693	127	40	2154	125	250	2529	19.72
	Charging	3.78	34952	127	41.6	4369	250	-	4619	17.47
	TOTAL									37.19
Baseline Modified		7.2	36383	127	43.5	4438	250	250	4938	35.67
Baseline Original		7.8	33693	127	40	4308	250	250	4808	37.50

TABLE 4.15 RECONDENSER ENERGY CONSUMPTION

4.4.8 Heat Pump With Thermal Storage

This system saves energy by running the heat pump when outdoor air temperatures provide better efficiencies.

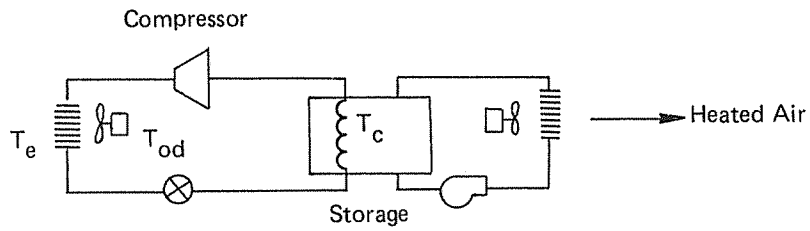


FIGURE 4.15 HEAT PUMP WITH THERMAL STORAGE

During the day when the outdoor temperature is 15°F higher than the evening, the heat pump is run continuously, charging thermal storage whenever possible. At night heat is supplied from storage. This operating philosophy is poor from the utility viewpoint as it increases their peak load.

The equations used to describe the heat pump operation are:

$$Q_{heating} = \dot{m}_{ref} (125.3 - 49.05)$$

$$= 892\ T_e - 107\ T_c + 16084$$

$$E_{heating} = E_{cooling} = \text{Energy Input}$$

$$= .57\ T_c T_e - 34.5\ T_e + 3293$$

and for the heat exchangers

$$T_e = .8012\ T_{od} - 1.898 \qquad (\text{od} = \text{outdoor})$$

$$T_c = 77.3 + .753\ T_{od}$$

The building thermal load and the heat capacity vs outdoor temperature are shown in Figure 4.16.

The expected performance of a standard unit is:

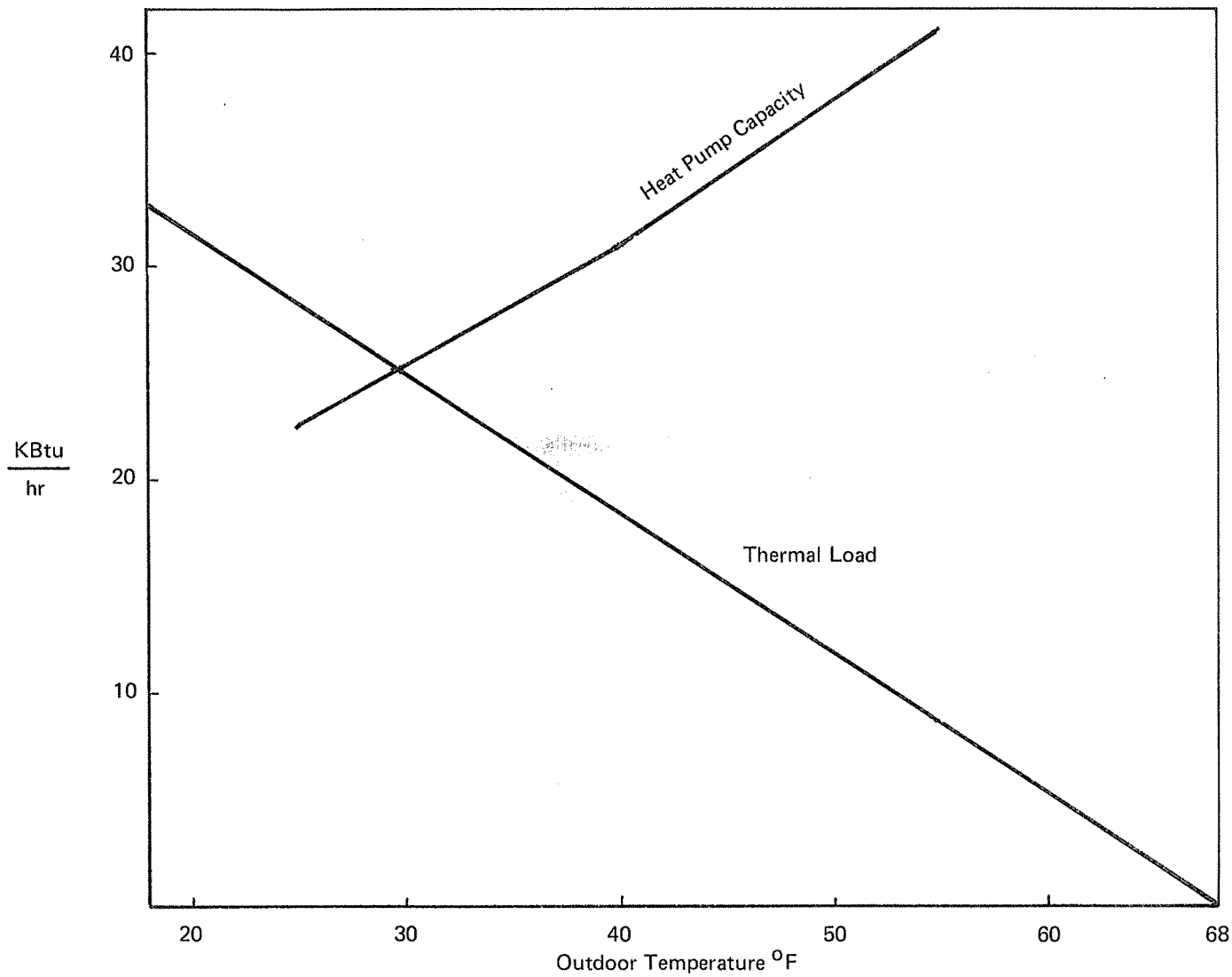


FIGURE 4.16 ASSUMED BUILDING LOAD AND HEAT PUMP CAPACITY AS A FUNCTION OF OUTDOOR TEMPERATURE

	Outdoor Temp. (°F)	Temperature (°F)		$Q_{heating}$ (Btu/hr)	Input Watts	COP
		Evaporator	Condenser			
Day	55	42.1	118.7	40936	4688	2.56
Night	40	30.2	107.4	31483	4099	2.25

Based on heat pump load factors from Kelley,* the energy use is:

	Outdoor Temp. (°F)	Load Factor	$\frac{COP_{actual}}{COP_{s.s}}$	$Q_{heating}$ (btu/day)	Input (kwh/day)
Day	55	0.20	0.90	98,246	12.50
Night	40	0.57	0.90	215,343	31.15
TOTAL				313,589	43.65

For a unit run continuously in the day, using thermal storage

	Temperature (°F)			$Q_{heating}$ (Btu/hr)	Input (watts)	Run Hrs	Load Factor	$\frac{COP_{actual}}{COP_{s.s}}$	Input (kwh/day)
	Outdoor	T_{evap}	$T_{condenser}$**						
Charging Day	55	42.1	128.7	39866	4578***	7.86	0.65	0.90	40.85
Discharge Day	55	---	--	40936	250	2.64	--	--	0.66
Discharge Night	40	---	--	40936	250	5.26	--	--	1.31
TOTAL									42.82

there is a 0.8 kwh/day savings, or 1.8%

---

* Reference 12

** reflects a storage temperature of 118.7°F and a refrigerant temperature 10°F higher.

*** without 250 watts of evaporator fan power.

The annual savings will vary with region and diurnal temperature variation. In particular, at temperatures near or below 42°F, the evaporator coil will operate below 32°F and defrosting will be required. Various sources indicate that this will reduce the cyclic efficiency to a value of 0.74 to 0.88. In this analysis we have used a value of 0.8. For a 40°F day and a 35°F night, we expect a savings of 4.11 kwh/day in the defrost range as shown in Table 4.16.

The annual energy savings depends in a great measure on the outdoor conditions. For example, using the savings above, the following annual savings are estimated for the cities shown.

	Hours Temperature (°F) Ranges between: 65-40	40-20	20-0	Annual Savings (kwh)	Annual Savings ($)
Charlotte, NC	3571	1575	4	389	15.50
Hartford, CT	3375	2821	364	595	23.80

This thermal storage system will require substantial amounts of storage: 136 KBtu and 15 KBtu for cold day (40°F) and warm day (55°F) respectively. Using water with a temperature range from 108°F to 128°F for storage would require a 1300 gallon tank. During charging the compressor performance would be affected as follows:

Effect of Sensible Heat Thermal Storage

Evaporator	Condenser	Q	W	COP
30.15	118	30351	4280	2.079
30.15	129	29281	4452	1.928
30.15	138	28524	4639	1.803
	Average	29385	4452	1.933

TABLE 4.16

ENERGY SAVINGS WHEN OUTDOOR TEMPERATURE IN DEFROST RANGE

Standard Heat Pump

	Evaporator	Condenser	Q	W	$W_{auxiliary}$	Load Factor	$\frac{COP_{actual}}{COP_{s.s.}}$	kwh/day
Day (40°F)	30.15	107.43	31483	4095	0	0.57	0.9	31.11
Night (35°F)	18.14	90.96	22532	3608	1603.5	1.00	0.8	71.90
TOTAL								103.01

With Daytime Storage

	Hrs.	Evap.	Condenser	Q	W	W_{aux}	Load Factor	$\frac{COP_{actual}}{COP_{s.s.}}$	kwh/day
Day (40°F) Charging	12.00	30.2	128	29381	4202	-	1.00	1.0	50.42
Discharge	5.26	-	-		250	-			1.31
Night (35°F)									
Discharge	8.20	-	-	40936	250	-			2.05
Charging	11.31	18.4	128	17676	3990	0	0.90	0.8	45.12
									98.9

Thus the use of the average COP over the $\pm$ 10°F range of condenser temperature doesn't introduce a significant error.

The heat exchanger used in the tank is sized for a 10°F difference at 40.9 KBtu/hr heat transfer rate. This requires a UA = 4090 Btu/hr °F. A free convection coefficient of 80 Btu/hr sq ft °F can be expected. This leads to a surface area of 51 sq. ft.

The cost of these two system components is estimated to be:

- Heat exchanger $ 200
- Tank 1220
- Total 1420

There is no savings for off peak use since the storage system is charged during the day.

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APPENDIX A

APPENDIX A

STATEMENT OF WORK

Arthur D. Little will provide to Oak Ridge National Laboratory certain information that will assist ERDA in planning and setting priorities for research, development, and demonstration of appliances which incorporate energy storage. Specifically, Arthur D. Little will conduct an unbiased comprehensive investigation of energy storage applications to residential and commercial appliances to determine potentials for energy savings, to identify technical options and evaluate their feasibilities, to identify and evaluate the barriers to commercialization, and to identify areas in which ERDA-RD&D funding would accelerate the use of such appliances in order to achieve significant national energy savings. The work will be monitored by an Oak Ridge National Laboratory Technical Manager (ORNL TM).

It is intended that the primary emphasis be on residential appliances which include water heaters, refrigerators, freezers, room air conditioners, ranges, ovens, dryers, washers, dishwashers, television sets and lighting. However, Arthur D. Little will investigate and report on new, innovative residential and commercial central space conditioning devices and other commercial appliances. Energy storage application to appliances includes thermal, chemical, mechanical, and electrical means or devices.

Task 1

Deliverable 1D. Submit a detailed project plan for review and approval by the ORNL TM. This plan shall show final allocation of financial and personnel resources, timing of principal events that are to occur during execution of the project, decision points and progress milestones, technical approach and methodology, and other items of direct relevance to timely and successful accomplishment of the project objectives.

Deliverable 1F. Submit a final project plan reflecting resolution of comments from the ORNL TM review of Deliverable 1D.

Athur D. Little, Inc., will not proceed with Task 2 or beyond until this plan is approved by the ORNL TM. No changes shall be made to the approved plan without prior approval of the ORNL TM.

Schedule and Distribution

Deliverable	Schedule	No. of copies to ORNL TM
1D	Within 15 days of signing the contract.	3
1F	Within 10 days after the ORNL review. Allow 10 days for the ORNL review.	8

Task 2

Conduct studies and investigations necessary to determine the potential for energy savings by incorporating energy storage in residential and commercial appliances. Energy savings may occur from increased efficiency of the appliance, more efficient use of the appliance, increased efficiencies in utility supply distribution of energy, or a shift to a more abundant energy source. Arthur D. Little will develop and apply a screening method to identify candidates for further study.

Task 3

Establish the feasibility of the candidate devices or methods selected in Task 2. Included in the feasibility analysis will be the technical possibilities, economic constraints, barriers to commercialization, and socio-legal risks to implementation. Develop and apply a ranking method to establish a priority list of candidate devices.

Task 4

Identify the candidate devices whose commercialization would be accelerated by ERDA participation. This is in contrast to those developments which will occur in the marketplace without government involvement. Develop and apply a ranking method to establish a final priority list of candidate device developments.

Deliverable 4D. Submit, for review by the ORNL TM, a summary interim report documenting all aspects of Tasks 2, 3, and 4. Eight copies of the report are due within 5 months of signing the contract.

Task 5

Develop research, development, and demonstration project plans for the candidate appliances identified in Task 4. The plan must include, in addition to the RD&D needs, a proposed route to commercialization. The commercialization plan will include proposed solutions to overcoming the identified risks and barriers.

Task 6

Deliverable 6D. Submit, for review by the ORNL TM, a report documenting all aspects of the project including (a) the results, conclusions, and recommendations of the project and (b) data, assumptions and methodology which were used to develop the conclusions and recommendations of the project.

Deliverable 6F. Submit a final report for the project reflecting resolution of comments from the ORNL TM review of Deliverable 6D.

Schedule and Distribution

Deliverable	Schedule	No. of copies to ORNL TM
6D	Within 7 months of signing the contract.	8
6F	Within 1 months after the ORNL review. Allow 2 weeks for ORNL review.	200 and camera ready copy

Additional Deliverables

In addition to the deliverables described above, Arthur D. Little will do the following:

Submit eight copies, to the Oak Ridge National Laboratory Technical Manager (ORNL TM) by the tenth day of each calendar month, of a monthly report of costs, manpower, and schedules compared to the approved program plan. A narrative of progress and events shall be included as part of the monthly report and shall highlight any problems and the Arthur Little's solution.

Conduct informal briefings at the Arthur D. Little facility as required. It is anticipated that the briefings will occur at the completion of Task A and Task 5 following ORNL TM review of any deliverables due at these times.

APPENDIX B

APPENDIX B

DERIVATION OF ENERGY USE ESTIMATES

This appendix describes the derivation of energy use estimates which were not developed in Reference 1: Integrated Appliances.

B.1 Dishwashers

Dishwashers require two major sources of energy. The first is an electric resistance heater which heats the water and dries the dishes. The second is the motor which circulates the water during the washing cycle. This excludes the energy required for heating the water initially, which is supplied by the hot water heater as the hot water heater is treated separately. Data from references (FEA/NBS) indicates an average of .67 killowatt hours per load are required for a typical dishwasher. Further, it characterizes the typical dishwasher as having a 1/3 horsepower motor and 1,000 watt heater. We have assumed that the motor operates for 20 minutes during the cycle and that the electric heater cycles off and on during a typical one hour cycle with a total on time for the heater during this period of 35 minutes. This gives a breakdown for the energy use as follows:

Motor:	80 watt hours
Heater:	590 watt hours
Total....	670 watt hours per cycle

This reference also estimates that 416 cycles per year are typical for a dishwasher. This yields a total energy use as indicated in Chapter 2.

B.2 Clothes Washing

FEA/NBS (reference 3) estimates that a .22 killowatt hours per load for 412 loads per year are typical for a clothes washer. This yields the energy consumption shown.

B.3 Clothes Dryers

Table B-1 summarizes the energy use breakdown for clothes dryers. The energy use estimates for heating the air and for standby losses for gas dryers were taken from reference 1 (Integrated Appliances). The motor consumptions were calculated using estimates of the percent of the total energy consumption required by motors and controls from reference 3 (FEA/NBS). FEA/NBS estimates that 4% of the total annual usage for gas dryers is used for the motor and control, and 13% of the annual input for electric dryers is used for motors and controls. We have assumed that the portion of this input required for controls is negligable compared to that required for the motors in analyzing the effect of powering motors using off-peak energy.

TABLE B-1

CLOTHES DRYER ENERGY USE

DWELLING TYPE	FUNCTION	ENERGY USE (10^6 BTU/YR)	
		GAS	ELECTRIC
Single Family & Duplex	Heat Air	5.30	4.20
	Pilot	2.85	-
	Motor	0.34	0.63
	Total	8.49	4.83
Mobile Home	Heat Air	7.40	7.02
	Pilot	2.60	-
	Motor	0.42	1.05
	Total	10.42	8.07
Low-Rise Apartment	Heat Air	18.86	13.20
	Pilot	6.64	-
	Motor	1.06	2.00
	Total	26.56	15.20

B.4 Televisions

Reference 3 (FEA/NBS) estimates that $1.5X10^6$ Btu's per year are used by color TV's and $.9X10^6$ Btu's per year are used by black and white TV's. We have assumed that the saturation of TV's in single family homes, mobile homes and apartment buildings is as shown in Table B-2, which leads to the average energy consumptions shown.

TABLE B-2

ENERGY USE FOR TELEVISIONS

	SATURATION		ENERGY USE (10^6 BTU)* PER APPLIANCE TYPE PER RESIDENCE PER YEAR
	B&W	COLOR	
Single Family	0.97	0.90	2.22
Mobile Home	0.25	0.75	1.35
Low-Rise Apartment	0.33	0.67	1.30

*Based on: Color T.V. 1.5×10^6 Btu/yr.
B&W T.V. 0.9×10^6 Btu/yr.
From Reference 3 (FEA/NBS)

APPENDIX C

APPENDIX C

DETAILED LOAD CURVES AND SIMULATION RESULTS

The following pages to this Appendix present detailed baseline load curves and the generation mix for the baseline case and the different off-peak cases considered.* The off-peak cases were generated by shifting the load for the different appliances to nighttime hours using the duty cycles given in Appendix E. The time periods during which input to the appliances was assumed to be shut off are summarized below.

INPUT TO APPLIANCE

	Off	On
Refrigerator	6 am	Midnight
Water Heating		
4 Hours	6 pm	10 pm
8 Hours	2 pm	10 pm
16 Hours	6 am	10 pm
Space Heating (Winter Peaking Utility Only)	8 am	10 pm
Lighting		
in Winter	6 am	11 pm
in Summer	7 pm	11 pm
Television	7 am	11 pm
Ranges and Ovens	3 pm	7 pm
Air Conditioning	8 am	8 pm
Clothes Dryers	8 am	9 pm
Clothes Washers	8 am	9 pm
Dishwashers	5 pm	9 pm

All appliance storage devices are full by 6 am.

* The abbreviations are explained on Page C-3

TABLE NOMENCLATURE

ID. No.-	Identification number, assigned to the unit by the user.
Max. Cap.-	Maximum capacity in megawatts, input to program.
Max. Load-	Maximum load in megawatts, calculated in program.
Forced Outage Rate-	Fraction of available time unit off due to unscheduled outages.
Min. Down Time-	Minimum number of hours a unit must be down before being able to be started again; input to program.
Hrs. on Line-	Total number of hours in the year during which the unit operated.
Cap. Fac-	Capacity factor, defined as actual energy output per year divided by (hours per year times maximum capacity).
Avg. Oper. Ht. Rt-	Average operating heat rate.
Oper/Maint. Cost-	Operation and maintenance costs.
Fuel Inv. Cost-	The cost of fuel in inventory at the end of the year.
Tieaid -	The name given to purchased energy

SATURDAY LOAD MODEL FOR A SUMMER PEAKING UTILITY

Fraction of Annual Peak Load Energy by Hour*

Time Period**	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
0	0.544	0.544	0.470	0.460	0.460	0.430	0.540	0.600	0.540	0.480	0.450	0.530
2	0.544	0.544	0.470	0.460	0.460	0.430	0.540	0.600	0.540	0.480	0.450	0.530
2	0.504	0.504	0.450	0.438	0.438	0.456	0.513	0.570	0.522	0.464	0.435	0.491
3	0.504	0.504	0.450	0.438	0.438	0.456	0.513	0.570	0.522	0.464	0.435	0.491
4	0.504	0.504	0.473	0.460	0.460	0.456	0.513	0.570	0.531	0.472	0.443	0.491
5	0.504	0.504	0.473	0.460	0.460	0.456	0.513	0.570	0.531	0.472	0.443	0.491
6	0.512	0.512	0.510	0.496	0.496	0.512	0.576	0.640	0.594	0.528	0.495	0.499
7	0.512	0.512	0.510	0.496	0.496	0.512	0.576	0.640	0.594	0.528	0.495	0.499
8	0.720	0.720	0.698	0.679	0.679	0.654	0.747	0.830	0.846	0.752	0.705	0.702
9	0.720	0.720	0.698	0.679	0.679	0.654	0.747	0.830	0.846	0.752	0.705	0.702
10	0.776	0.776	0.713	0.694	0.694	0.760	0.855	0.950	0.873	0.776	0.728	0.767
11	0.776	0.776	0.713	0.694	0.694	0.760	0.855	0.950	0.873	0.776	0.728	0.767
12	0.696	0.696	0.690	0.672	0.672	0.776	0.873	0.970	0.837	0.744	0.697	0.757
13	0.696	0.696	0.690	0.672	0.672	0.776	0.873	0.970	0.837	0.744	0.697	0.757
14	0.672	0.672	0.713	0.694	0.694	0.792	0.891	0.990	0.819	0.728	0.683	0.679
15	0.672	0.672	0.713	0.694	0.694	0.792	0.891	0.990	0.819	0.728	0.683	0.679
16	0.736	0.736	0.668	0.650	0.650	0.800	0.900	1.000	0.855	0.760	0.712	0.655
17	0.736	0.736	0.668	0.650	0.650	0.800	0.900	1.000	0.855	0.760	0.712	0.655
18	0.800	0.800	0.750	0.730	0.730	0.776	0.873	0.970	0.900	0.800	0.750	0.730
19	0.800	0.800	0.750	0.730	0.730	0.776	0.873	0.970	0.900	0.800	0.750	0.730
20	0.752	0.752	0.728	0.708	0.708	0.736	0.828	0.920	0.765	0.680	0.638	0.733
21	0.752	0.752	0.728	0.708	0.708	0.736	0.828	0.920	0.765	0.680	0.638	0.733
22	0.534	0.534	0.585	0.569	0.569	0.568	0.639	0.710	0.657	0.584	0.548	0.569
23	0.534	0.534	0.585	0.569	0.569	0.568	0.639	0.710	0.657	0.584	0.548	0.569

*1.000 = 6000 megawatts

** Load for 1 hour period following time indicated; 0 hour is midnight

SUNDAY LOAD MODEL FOR A SUMMER PEAKING UTILITY

Fraction of Annual Peak Load Energy by Hour*

Time Period**	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
0	0.535	0.535	0.465	0.453	0.453	0.504	0.567	0.630	0.540	0.480	0.450	0.523
1	0.535	0.535	0.465	0.453	0.453	0.504	0.567	0.630	0.540	0.480	0.450	0.523
2	0.526	0.526	0.473	0.460	0.460	0.496	0.558	0.620	0.540	0.480	0.450	0.515
3	0.526	0.526	0.473	0.460	0.460	0.496	0.558	0.620	0.540	0.480	0.450	0.515
4	0.552	0.552	0.495	0.482	0.482	0.520	0.585	0.650	0.630	0.560	0.525	0.538
5	0.552	0.552	0.495	0.482	0.482	0.520	0.585	0.650	0.630	0.560	0.525	0.538
6	0.752	0.752	0.750	0.730	0.730	0.630	0.765	0.850	0.900	0.800	0.750	0.733
7	0.752	0.752	0.750	0.730	0.730	0.630	0.765	0.850	0.900	0.800	0.750	0.733
8	0.654	0.654	0.623	0.606	0.606	0.632	0.711	0.790	0.693	0.616	0.578	0.647
9	0.654	0.654	0.623	0.606	0.606	0.632	0.711	0.790	0.693	0.616	0.578	0.647
10	0.712	0.712	0.608	0.591	0.591	0.728	0.819	0.910	0.765	0.680	0.638	0.694
11	0.712	0.712	0.608	0.591	0.591	0.728	0.819	0.910	0.765	0.680	0.638	0.694
12	0.600	0.630	0.600	0.584	0.584	0.752	0.846	0.940	0.747	0.664	0.623	0.663
13	0.600	0.630	0.600	0.584	0.584	0.752	0.846	0.940	0.747	0.664	0.623	0.663
14	0.640	0.640	0.555	0.540	0.540	0.768	0.864	0.960	0.729	0.643	0.608	0.624
15	0.640	0.640	0.555	0.540	0.540	0.768	0.864	0.960	0.729	0.643	0.608	0.624
16	0.696	0.696	0.570	0.555	0.555	0.800	0.900	1.000	0.801	0.712	0.668	0.679
17	0.696	0.696	0.570	0.555	0.555	0.800	0.900	1.000	0.801	0.712	0.668	0.679
18	0.800	0.800	0.638	0.621	0.621	0.734	0.882	0.980	0.828	0.736	0.690	0.780
19	0.800	0.800	0.638	0.621	0.621	0.734	0.882	0.980	0.828	0.736	0.690	0.780
20	0.768	0.768	0.683	0.664	0.664	0.752	0.846	0.940	0.765	0.680	0.638	0.749
21	0.768	0.768	0.683	0.664	0.664	0.752	0.846	0.940	0.765	0.680	0.638	0.749
22	0.584	0.534	0.585	0.569	0.569	0.640	0.720	0.800	0.567	0.504	0.473	0.569
23	0.584	0.534	0.585	0.569	0.569	0.640	0.720	0.800	0.567	0.504	0.473	0.569

*1.000 = 6000 megawatts

**Load for 1 hour period following time indicated; 0 hour is midnight

WEEKDAY LOAD MODEL FOR A SUMMER PEAKING UTILITY

Fraction of Annual Peak Load Energy by Hour*

Time Period**	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
0	0.504	0.504	0.450	0.438	0.438	0.443	0.504	0.560	0.513	0.456	0.428	0.491
1	0.504	0.504	0.450	0.438	0.438	0.443	0.504	0.560	0.513	0.456	0.428	0.491
2	0.480	0.480	0.443	0.431	0.431	0.432	0.486	0.540	0.513	0.456	0.428	0.468
3	0.480	0.480	0.443	0.431	0.431	0.432	0.486	0.540	0.513	0.456	0.428	0.468
4	0.483	0.483	0.465	0.453	0.453	0.472	0.531	0.590	0.531	0.472	0.443	0.476
5	0.483	0.483	0.465	0.453	0.453	0.472	0.531	0.590	0.531	0.472	0.443	0.476
6	0.624	0.624	0.593	0.577	0.577	0.534	0.657	0.730	0.675	0.600	0.563	0.608
7	0.624	0.624	0.593	0.577	0.577	0.534	0.657	0.730	0.675	0.600	0.563	0.603
8	0.768	0.768	0.756	0.730	0.730	0.744	0.837	0.930	0.864	0.768	0.720	0.749
9	0.768	0.768	0.756	0.730	0.730	0.744	0.837	0.930	0.864	0.768	0.720	0.749
10	0.734	0.734	0.735	0.715	0.715	0.768	0.864	0.960	0.846	0.752	0.705	0.764
11	0.734	0.734	0.735	0.715	0.715	0.768	0.864	0.960	0.846	0.752	0.705	0.764
12	0.720	0.720	0.720	0.701	0.701	0.734	0.882	0.980	0.855	0.760	0.713	0.702
13	0.720	0.720	0.720	0.701	0.701	0.734	0.882	0.980	0.855	0.760	0.713	0.702
14	0.704	0.704	0.713	0.694	0.694	0.800	0.900	1.000	0.837	0.744	0.693	0.686
15	0.704	0.704	0.713	0.694	0.694	0.800	0.900	1.000	0.837	0.744	0.693	0.686
16	0.760	0.760	0.693	0.679	0.679	0.792	0.891	0.990	0.873	0.776	0.728	0.741
17	0.760	0.760	0.693	0.679	0.679	0.792	0.891	0.990	0.873	0.776	0.728	0.741
18	0.800	0.800	0.720	0.701	0.701	0.760	0.855	0.950	0.900	0.800	0.750	0.780
19	0.800	0.800	0.720	0.701	0.701	0.760	0.855	0.950	0.900	0.800	0.750	0.780
20	0.736	0.736	0.675	0.657	0.657	0.630	0.765	0.850	0.765	0.680	0.638	0.718
21	0.736	0.736	0.675	0.657	0.657	0.630	0.765	0.850	0.765	0.680	0.638	0.718
22	0.544	0.544	0.510	0.496	0.496	0.504	0.567	0.630	0.535	0.520	0.483	0.530
23	0.544	0.544	0.510	0.496	0.496	0.504	0.567	0.630	0.535	0.520	0.483	0.530

* 1.000 = 6000 megawatts

** Load for 1 hour period following time indicated; 0 hour is midnight.

BASELINE COSTS OF SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE 0.06
OPERATION + MAINTENANCE INFLATION FACTOR 0.03
PEAK LOAD (MW) 6000.00
THERMAL PEAK (MW) 5400.00

SPINNING RESERVE REQUIREMENT 0.
NIGHTLY PEAK LOAD ADDER (MW) 0.
MAXIMUM CAPACITY (MW) 6400.00
CONTINUOUS CAPACITY (MW) 6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	APR 21	JUN 8	6318	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	NOV 3	DEC 7	6437	0.73	9501.	3205289.	40.346	0.	5.21	0.	45.555	1.325
12	COAL8	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.76	9599.	2684633.	34.143	0.	4.64	0.	33.779	1.325
13	COAL9	400.0	400.0	0.150	168	NOV 24	DEC 28	6750	0.76	9600.	2677373.	34.052	0.	4.63	0.	33.682	1.325
17	OIL67	800.0	800.0	0.230	168	APR 7	APR 20	6505	0.71	9306.	4972619.	104.732	0.	8.28	0.	113.014	2.263
10	COAL7	300.0	300.0	0.100	3	FEB 11	MAR 9	6434	0.71	9714.	1867720.	24.038	0.	4.17	0.	28.204	1.325
7	COAL5	200.0	200.0	0.070	3	MAR 10	APR 6	6141	0.68	10016.	1190103.	15.793	0.	3.07	0.	18.867	1.325
8	COAL6	200.0	200.0	0.070	3	FEB 4	MAR 2	5716	0.63	10021.	1103780.	14.655	0.	2.99	0.	17.650	1.325
3	COAL3	100.0	100.0	0.060	3	APR 7	APR 27	5575	0.62	12005.	546083.	8.686	0.	1.73	0.	10.415	1.325
4	COAL4	100.0	100.0	0.060	3	APR 28	MAY 18	5406	0.60	12017.	522967.	8.326	0.	1.70	0.	10.031	1.325
2	COAL2	100.0	100.0	0.060	3	JUN 9	JUN 29	5262	0.58	12013.	509947.	8.116	0.	1.69	0.	9.807	1.325
1	COAL1	100.0	100.0	0.060	3	DEC 8	DEC 28	5069	0.55	12017.	487103.	7.755	0.	1.67	0.	9.423	1.325
16	OIL66	600.0	600.0	0.220	2	MAR 3	APR 6	4159	0.41	9425.	2171939.	46.331	0.	4.22	0.	50.554	2.263
15	OIL65	500.0	500.0	0.190	2	JAN 7	FEB 10	3540	0.30	9550.	1326419.	28.672	0.	3.68	0.	32.357	2.263
11	OIL64	300.0	300.0	0.100	2	JUN 9	JUL 6	2419	0.21	9817.	562263.	12.493	0.	2.96	0.	15.449	2.263
9	OIL63	200.0	212.2	0.070	2	OCT 27	NOV 23	1574	0.15	10098.	263237.	6.017	0.	2.21	0.	8.232	2.263
5	OIL61	100.0	100.8	0.060	2	DEC 8	DEC 28	1223	0.12	12074.	103025.	2.815	0.	1.27	0.	4.082	2.263
6	OIL62	100.0	97.1	0.060	2	JUN 9	JUN 29	983	0.09	12089.	81572.	2.232	0.	1.24	0.	3.476	2.263
31	NAT13	100.0	85.0	0.150	1	SEP 29	OCT 26	736	0.07	12300.	61909.	3.027	0.	0.60	0.	3.625	3.975
32	NAT14	100.0	85.0	0.150	1	APR 28	MAY 25	674	0.06	12299.	53097.	2.596	0.	0.60	0.	3.191	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 10	NOV 30	587	0.06	14041.	24680.	1.377	0.	0.30	0.	1.675	3.975
28	NAT10	50.0	43.0	0.140	1	APR 7	APR 27	535	0.05	14049.	22435.	1.253	0.	0.30	0.	1.549	3.975
29	NAT11	50.0	43.0	0.140	1	DEC 8	DEC 23	452	0.04	14036.	19116.	1.066	0.	0.30	0.	1.362	3.975
30	NAT12	50.0	43.0	0.140	1	JAN 7	JAN 27	408	0.04	14045.	17153.	0.958	0.	0.29	0.	1.253	3.975
25	NAT7	25.0	22.3	0.110	1	FEB 18	MAR 2	367	0.04	14517.	8087.	0.467	0.	0.15	0.	0.614	3.975
26	NAT8	25.0	22.3	0.110	1	JUN 16	JUN 29	347	0.03	14519.	7645.	0.441	0.	0.15	0.	0.583	3.975
21	NAT3	25.0	22.3	0.110	1	FEB 11	FEB 24	335	0.03	14518.	7405.	0.427	0.	0.15	0.	0.574	3.975
22	NAT4	25.0	22.3	0.110	1	JUN 9	JUN 22	322	0.03	14534.	7068.	0.408	0.	0.15	0.	0.555	3.975
23	NAT5	25.0	22.3	0.110	1	OCT 6	OCT 19	290	0.03	14512.	6408.	0.370	0.	0.15	0.	0.516	3.975
24	NAT6	25.0	22.3	0.110	1	NOV 10	NOV 23	284	0.03	14516.	6306.	0.364	0.	0.15	0.	0.511	3.975
19	NAT1	25.0	22.3	0.110	1	NOV 10	NOV 23	274	0.03	14516.	6069.	0.350	0.	0.15	0.	0.497	3.975
20	NAT2	25.0	22.3	0.110	1	NOV 10	NOV 23	266	0.03	14513.	5876.	0.339	0.	0.15	0.	0.486	3.975
	TIEAID										85444.	0.513				0.513	6.000
	THERMAL TOTALS										29666502.	446.626	0.	65.32	0.	511.950	
	PRESENT VALUE OF TOTALS											421.345	0.	61.63	0.	482.972	

ANNUAL LOAD ENERGY (MWHRS) 34936902.

Arthur D Little, Inc.

REFRIGERATOR COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06
OPERATION + MAINTENANCE INFLATION FACTOR	0.03
PEAK LOAD (MW)	6000.00
THERMAL PEAK (MW)	5112.00

SPINNING RESERVE REQUIREMENT	0.
NIGHTLY PEAK LOAD ADDER (MW)	0.
MAXIMUM CAPACITY (MW)	6400.00
CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	APR 21	JUN 8	6318	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	NOV 3	DEC 7	6437	0.73	9500.	3217320.	40.495	0.	5.22	0.	45.714	1.325
12	COAL8	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.77	9600.	2699721.	34.337	0.	4.65	0.	38.986	1.325
13	COAL9	400.0	400.0	0.150	168	NOV 24	DEC 23	6750	0.77	9600.	2698937.	34.327	0.	4.65	0.	38.975	1.325
17	OIL67	800.0	800.0	0.230	168	APR 7	APR 20	6505	0.73	9300.	5115238.	107.674	0.	8.38	0.	116.055	2.263
10	COAL7	300.0	300.0	0.100	3	FEB 11	MAR 9	7145	0.81	9701.	2131444.	27.394	0.	4.41	0.	31.805	1.325
7	COAL5	200.0	200.0	0.070	3	MAR 10	APR 6	7101	0.80	10004.	1401542.	18.576	0.	3.27	0.	21.847	1.325
8	COAL6	200.0	200.0	0.070	3	FEB 4	MAR 2	6741	0.74	10014.	1305568.	17.322	0.	3.18	0.	20.504	1.325
3	COAL3	100.0	100.0	0.060	3	APR 7	APR 27	6320	0.69	12012.	607765.	9.672	0.	1.79	0.	11.466	1.325
4	COAL4	100.0	100.0	0.060	3	APR 28	MAY 18	6032	0.64	12030.	566195.	9.024	0.	1.75	0.	10.774	1.325
2	COAL2	100.0	100.0	0.060	3	JUN 9	JUN 29	5827	0.62	12024.	546724.	8.709	0.	1.73	0.	10.439	1.325
1	COAL1	100.0	100.0	0.060	3	DEC 8	DEC 28	5439	0.57	12038.	501247.	7.995	0.	1.68	0.	9.677	1.325
16	OIL66	600.0	600.0	0.220	2	MAR 3	APR 6	4532	0.39	9452.	2071172.	44.308	0.	4.15	0.	48.461	2.263
15	OIL65	500.0	500.0	0.190	2	JAN 7	FEB 10	3113	0.23	9611.	1003196.	21.823	0.	3.42	0.	25.246	2.263
11	OIL64	300.0	300.0	0.100	2	JUN 9	JUL 6	1640	0.13	9895.	349959.	7.838	0.	2.76	0.	10.597	2.263
9	OIL63	200.0	185.9	0.070	2	OCT 27	NOV 23	988	0.09	10182.	151706.	3.496	0.	2.11	0.	5.608	2.263
5	OIL61	100.0	94.0	0.060	2	DEC 8	DEC 28	659	0.06	12110.	53331.	1.462	0.	1.21	0.	2.677	2.263
6	OIL62	100.0	94.0	0.060	2	JUN 9	JUN 29	502	0.05	12088.	41620.	1.139	0.	1.20	0.	2.341	2.263
31	NAT13	100.0	85.0	0.150	1	SEP 29	OCT 26	410	0.04	12392.	31441.	1.549	0.	0.59	0.	2.138	3.975
32	NAT14	100.0	85.0	0.150	1	APR 28	MAY 25	351	0.03	12440.	26262.	1.299	0.	0.59	0.	1.886	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 10	NOV 30	270	0.03	14045.	11336.	0.633	0.	0.29	0.	0.926	3.975
28	NAT10	50.0	43.0	0.140	1	APR 7	APR 27	245	0.02	14044.	10331.	0.577	0.	0.29	0.	0.870	3.975
29	NAT11	50.0	43.0	0.140	1	DEC 8	DEC 28	217	0.02	14042.	9084.	0.507	0.	0.29	0.	0.800	3.975
30	NAT12	50.0	43.0	0.140	1	JAN 7	JAN 27	195	0.02	14067.	8098.	0.453	0.	0.29	0.	0.745	3.975
25	NAT7	25.0	22.2	0.110	1	FEB 18	MAR 2	166	0.02	14521.	3667.	0.212	0.	0.15	0.	0.358	3.975
26	NAT8	25.0	22.2	0.110	1	JUN 16	JUN 29	153	0.02	14538.	3355.	0.194	0.	0.15	0.	0.340	3.975
21	NAT3	25.0	22.2	0.110	1	FEB 11	FEB 24	144	0.01	14518.	3162.	0.182	0.	0.15	0.	0.328	3.975
22	NAT4	25.0	22.2	0.110	1	JUN 9	JUN 22	139	0.01	14539.	3034.	0.175	0.	0.15	0.	0.321	3.975
23	NAT5	25.0	22.2	0.110	1	OCT 6	OCT 19	129	0.01	14515.	2811.	0.162	0.	0.15	0.	0.308	3.975
24	NAT6	25.0	22.2	0.110	1	NOV 10	NOV 23	127	0.01	14536.	2731.	0.158	0.	0.15	0.	0.304	3.975
19	NAT1	25.0	22.2	0.110	1	NOV 10	NOV 23	118	0.01	14543.	2529.	0.146	0.	0.15	0.	0.292	3.975
20	NAT2	25.0	22.2	0.110	1	NOV 10	NOV 23	106	0.01	14520.	2334.	0.135	0.	0.15	0.	0.280	3.975
	TIEAID										32223.	0.193				0.193	6.000
	THERMAL TOTALS										29666344.	435.635	0.	65.49	0.	501.122	
	PRESENT VALUE OF TOTALS											410.976	0.	61.78	0.	472.756	

ANNUAL LOAD ENERGY (MWHRS) 34936950.

Arthur D Little Inc.

4-HOUR WATER HEATING COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	6000.00	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5400.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	APR 21	JUN 8	6318	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAR 3	APR 6	6437	0.73	9500.	3216970.	40.491	0.	5.22	0.	45.710	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 24	DEC 28	6750	0.77	9600.	2696948.	34.301	0.	4.65	0.	38.948	1.325
13	COAL9	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.77	9599.	2693194.	34.253	0.	4.64	0.	38.896	1.325
17	OIL67	800.0	800.0	0.230	168	APR 7	APR 20	6505	0.72	9301.	5072075.	106.777	0.	8.35	0.	115.128	2.263
10	COAL7	300.0	300.0	0.100	3	FEB 11	MAR 9	6969	0.78	9704.	2064800.	26.546	0.	4.35	0.	30.895	1.325
7	COAL5	200.0	200.0	0.070	3	MAR 10	APR 6	6713	0.74	10012.	1306578.	17.332	0.	3.18	0.	20.514	1.325
8	COAL6	200.0	200.0	0.070	3	FEB 4	MAR 2	6341	0.69	10028.	1209158.	16.064	0.	3.09	0.	19.157	1.325
3	COAL3	100.0	100.0	0.060	3	APR 7	APR 27	5962	0.65	12013.	573101.	9.121	0.	1.76	0.	10.878	1.325
4	COAL4	100.0	100.0	0.060	3	APR 28	MAY 18	5666	0.61	12023.	536561.	8.547	0.	1.72	0.	10.266	1.325
2	COAL2	100.0	100.0	0.060	3	OCT 13	NOV 2	5357	0.58	12024.	505553.	8.054	0.	1.69	0.	9.740	1.325
1	COAL1	100.0	100.0	0.060	3	JUN 9	JUN 29	5196	0.55	12029.	486840.	7.759	0.	1.67	0.	9.426	1.325
16	OIL66	600.0	600.0	0.220	2	NOV 3	DEC 7	4268	0.38	9447.	2020076.	43.193	0.	4.12	0.	47.311	2.263
15	OIL65	500.0	500.0	0.190	2	JAN 7	FEB 10	3185	0.26	9568.	1145636.	24.809	0.	3.54	0.	28.347	2.263
11	OIL64	300.0	300.0	0.100	2	JUN 9	JUL 6	1997	0.17	9839.	454943.	10.132	0.	2.86	0.	12.988	2.263
9	OIL63	200.0	211.2	0.070	2	DEC 1	DEC 28	1265	0.12	10106.	210243.	4.809	0.	2.17	0.	6.975	2.263
5	OIL61	100.0	100.8	0.060	2	JUN 9	JUN 29	952	0.09	12071.	80022.	2.186	0.	1.24	0.	3.429	2.263
6	OIL62	100.0	97.1	0.060	2	DEC 8	DEC 28	779	0.08	12059.	66552.	1.816	0.	1.23	0.	3.045	2.263
31	NAT13	100.0	85.0	0.150	1	JAN 7	FEB 3	624	0.06	12313.	48843.	2.390	0.	0.59	0.	2.985	3.975
32	NAT14	100.0	85.0	0.150	1	OCT 27	NOV 23	541	0.05	12304.	42557.	2.081	0.	0.59	0.	2.674	3.975
27	NAT9	50.0	43.0	0.140	1	FEB 11	MAR 2	460	0.04	14045.	19358.	1.081	0.	0.30	0.	1.376	3.975
28	NAT10	50.0	43.0	0.140	1	MAR 10	MAR 30	422	0.04	14043.	17777.	0.992	0.	0.30	0.	1.287	3.975
29	NAT11	50.0	43.0	0.140	1	SEP 29	OCT 19	369	0.04	14040.	15645.	0.873	0.	0.29	0.	1.168	3.975
30	NAT12	50.0	43.0	0.140	1	MAY 5	MAY 25	329	0.03	14051.	13855.	0.774	0.	0.29	0.	1.068	3.975
25	NAT7	25.0	22.2	0.110	1	SEP 29	OCT 12	290	0.03	14519.	6393.	0.369	0.	0.15	0.	0.516	3.975
26	NAT8	25.0	22.3	0.110	1	MAR 24	APR 6	280	0.03	14522.	6141.	0.354	0.	0.15	0.	0.501	3.975
21	NAT3	25.0	22.3	0.110	1	NOV 10	NOV 23	266	0.03	14521.	5838.	0.337	0.	0.15	0.	0.484	3.975
22	NAT4	25.0	22.3	0.110	1	FEB 11	FEB 24	252	0.03	14526.	5529.	0.319	0.	0.15	0.	0.466	3.975
23	NAT5	25.0	22.3	0.110	1	MAR 31	APR 13	236	0.02	14512.	5205.	0.300	0.	0.15	0.	0.447	3.975
24	NAT6	25.0	22.3	0.110	1	FEB 18	MAR 2	231	0.02	14515.	5048.	0.291	0.	0.15	0.	0.438	3.975
19	NAT1	25.0	22.3	0.110	1	NOV 10	NOV 23	222	0.02	14520.	4877.	0.282	0.	0.15	0.	0.428	3.975
20	NAT2	25.0	22.3	0.110	1	NOV 10	NOV 23	213	0.02	14516.	4678.	0.270	0.	0.15	0.	0.416	3.975
	TIEAID										68973.	0.414				0.414	6.000
	THERMAL TOTALS										29661678.	440.786	0.	65.40	0.	506.182	
	PRESENT VALUE OF TOTALS											415.836	0.	61.69	0.	477.530	

ANNUAL LOAD ENERGY (MWHRS) 34932078.

Arthur D Little, Inc.

8-HOUR WATER HEATING COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE 0.06
OPERATION + MAINTENANCE INFLATION FACTOR 0.03
PEAK LOAD (MW) 5928.00
THERMAL PEAK (MW) 5328.00

SPINNING RESERVE REQUIREMENT 0.
NIGHTLY PEAK LOAD ADDER (MW) 0.
MAXIMUM CAPACITY (MW) 6400.00
CONTINUOUS CAPACITY (MW) 6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM - THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	MAR 31 MAY 18	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	FEB 25 MAR 30	6436	0.73	9500.	3217116.	40.493	0.	5.22	0.	45.712	1.325
12	COAL8	400.0	400.0	0.150	168	OCT 20 NOV 23	6751	0.77	9600.	2697700.	34.311	0.	4.65	0.	38.958	1.325
13	COAL9	400.0	400.0	0.150	168	JUN 9 JUL 13	6750	0.77	9599.	2693089.	34.252	0.	4.64	0.	38.895	1.325
17	OIL67	800.0	800.0	0.230	168	MAY 26 JUN 8	6505	0.72	9302.	5064839.	106.630	0.	8.35	0.	114.975	2.263
10	COAL7	300.0	300.0	0.100	3	FEB 11 MAR 9	6993	0.79	9703.	2072925.	26.648	0.	4.36	0.	31.005	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 29 OCT 26	6945	0.77	10010.	1360035.	18.037	0.	3.23	0.	21.269	1.325
8	COAL6	200.0	200.0	0.070	3	OCT 27 NOV 23	6464	0.70	10024.	1237385.	16.434	0.	3.12	0.	19.552	1.325
3	COAL3	100.0	100.0	0.060	3	DEC 1 DEC 21	6162	0.66	12023.	582971.	9.286	0.	1.77	0.	11.054	1.325
4	COAL4	100.0	100.0	0.060	3	MAR 10 MAR 30	5738	0.62	12023.	540234.	8.606	0.	1.72	0.	10.329	1.325
2	COAL2	100.0	100.0	0.060	3	JUN 9 JUN 29	5416	0.58	12026.	507646.	8.089	0.	1.69	0.	9.778	1.325
1	COAL1	100.0	100.0	0.060	3	JUN 9 JUN 29	5122	0.54	12027.	478048.	7.617	0.	1.66	0.	9.275	1.325
16	OIL66	600.0	600.0	0.220	2	NOV 24 DEC 28	4315	0.39	9449.	2034350.	43.509	0.	4.13	0.	47.637	2.263
15	OIL65	500.0	500.0	0.190	2	JAN 7 FEB 10	3044	0.24	9580.	1072309.	23.251	0.	3.48	0.	26.729	2.263
11	OIL64	300.0	300.0	0.100	2	MAY 19 JUN 15	1801	0.16	9836.	411709.	9.165	0.	2.82	0.	11.982	2.263
9	OIL63	200.0	198.9	0.070	2	JAN 28 FEB 24	1182	0.11	10119.	193208.	4.425	0.	2.15	0.	6.575	2.263
5	OIL61	100.0	94.0	0.060	2	SEP 29 OCT 19	885	0.09	12061.	75511.	2.061	0.	1.24	0.	3.299	2.263
6	OIL62	100.0	94.0	0.060	2	JAN 7 JAN 27	720	0.07	12096.	59219.	1.621	0.	1.22	0.	2.842	2.263
31	NAT13	100.0	85.0	0.150	1	APR 28 MAY 25	579	0.05	12311.	45314.	2.217	0.	0.59	0.	2.811	3.975
32	NAT14	100.0	85.0	0.150	1	DEC 1 DEC 28	470	0.04	12292.	37262.	1.820	0.	0.59	0.	2.411	3.975
27	NAT9	50.0	43.0	0.140	1	JUN 9 JUN 29	402	0.04	14052.	16852.	0.941	0.	0.29	0.	1.236	3.975
28	NAT10	50.0	43.0	0.140	1	JUL 7 JUL 27	347	0.03	14044.	14600.	0.815	0.	0.29	0.	1.109	3.975
29	NAT11	50.0	43.0	0.140	1	FEB 4 FEB 24	335	0.03	14041.	14144.	0.789	0.	0.29	0.	1.083	3.975
30	NAT12	50.0	43.0	0.140	1	JUN 9 JUN 29	284	0.03	14049.	11936.	0.667	0.	0.29	0.	0.960	3.975
25	NAT7	25.0	22.3	0.110	1	JUN 16 JUN 29	266	0.03	14520.	5832.	0.337	0.	0.15	0.	0.483	3.975
26	NAT8	25.0	22.3	0.110	1	JUL 14 JUL 27	256	0.03	14530.	5608.	0.324	0.	0.15	0.	0.470	3.975
21	NAT3	25.0	22.3	0.110	1	MAY 12 MAY 25	245	0.02	14523.	5440.	0.314	0.	0.15	0.	0.461	3.975
22	NAT4	25.0	22.3	0.110	1	JUN 16 JUN 29	224	0.02	14536.	4920.	0.284	0.	0.15	0.	0.431	3.975
23	NAT5	25.0	22.3	0.110	1	JUL 14 JUL 27	206	0.02	14521.	4563.	0.263	0.	0.15	0.	0.410	3.975
24	NAT6	25.0	22.3	0.110	1	MAY 19 JUN 1	206	0.02	14520.	4519.	0.261	0.	0.15	0.	0.407	3.975
19	NAT1	25.0	22.3	0.110	1	JUL 14 JUL 27	190	0.02	14520.	4189.	0.242	0.	0.15	0.	0.388	3.975
20	NAT2	25.0	22.3	0.110	1	JUL 14 JUL 27	182	0.02	14513.	4023.	0.232	0.	0.15	0.	0.378	3.975
	TIEAID									60669.	0.364				0.364	6.000
	THERMAL TOTALS									29589876.	437.774	0.	65.36	0.	503.131	
	PRESENT VALUE OF TOTALS										412.994	0.	61.66	0.	474.652	

ANNUAL LOAD ENERGY (MWHRS) 34860276.

Arthur D Little, Inc.

16-HOUR WATER HEATING COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06
OPERATION + MAINTENANCE INFLATION FACTOR	0.03
PEAK LOAD (MW)	5928.00
THERMAL PEAK (MW)	5328.00
SPINNING RESERVE REQUIREMENT	0.
NIGHTLY PEAK LOAD ADDER (MW)	0.
MAXIMUM CAPACITY (MW)	6400.00
CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	APR 7	MAY 25	6320	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAR 3	APR 6	6437	0.73	9501.	3206850.	40.366	0.	5.21	0.	45.577	1.325
12	COAL8	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.76	9599.	2678468.	34.065	0.	4.63	0.	38.696	1.325
13	COAL9	400.0	400.0	0.150	168	FEB 11	MAR 16	6750	0.76	9599.	2668327.	33.936	0.	4.62	0.	38.559	1.325
17	OIL67	800.0	800.0	0.230	168	NOV 3	NOV 16	6505	0.72	9303.	5039443.	106.115	0.	8.33	0.	114.443	2.263
10	COAL7	300.0	300.0	0.100	3	MAY 26	JUN 22	7256	0.82	9706.	2149376.	27.641	0.	4.43	0.	32.069	1.325
7	COAL5	200.0	200.0	0.070	3	OCT 6	NOV 2	7282	0.81	10018.	1417409.	18.812	0.	3.29	0.	22.097	1.325
8	COAL6	200.0	200.0	0.070	3	FEB 4	MAR 2	6848	0.75	10022.	1315671.	17.470	0.	3.19	0.	20.661	1.325
3	COAL3	100.0	100.0	0.060	3	NOV 10	NOV 30	6617	0.68	12068.	596817.	9.542	0.	1.78	0.	11.324	1.325
4	COAL4	100.0	100.0	0.060	3	JAN 7	JAN 27	6196	0.63	12070.	556590.	8.901	0.	1.74	0.	10.641	1.325
2	COAL2	100.0	112.7	0.060	3	JUN 9	JUN 29	5820	0.60	12062.	523151.	8.360	0.	1.71	0.	10.065	1.325
1	COAL1	100.0	112.8	0.060	3	NOV 10	NOV 30	5455	0.55	12070.	484560.	7.749	0.	1.66	0.	9.414	1.325
16	OIL66	600.0	599.6	0.220	2	NOV 17	DEC 21	4528	0.39	9455.	2050949.	43.888	0.	4.14	0.	48.028	2.263
15	OIL65	500.0	499.7	0.190	2	JAN 7	FEB 10	2782	0.20	9611.	894594.	19.460	0.	3.33	0.	22.794	2.263
11	OIL64	300.0	319.2	0.100	2	DEC 1	DEC 28	1418	0.12	9887.	308555.	6.905	0.	2.72	0.	9.626	2.263
9	OIL63	200.0	199.1	0.070	2	MAR 17	APR 13	863	0.08	10161.	134730.	3.099	0.	2.10	0.	5.194	2.263
5	OIL61	100.0	4.0	0.060	2	JUN 9	JUN 29	566	0.05	12090.	46585.	1.275	0.	1.21	0.	2.483	2.263
6	OIL62	100.0	94.0	0.060	2	JAN 14	FEB 3	443	0.04	12076.	37505.	1.025	0.	1.20	0.	2.224	2.263
31	NAT13	100.0	85.0	0.150	1	SEP 29	OCT 26	360	0.03	12456.	26853.	1.330	0.	0.59	0.	1.917	3.975
32	NAT14	100.0	85.0	0.150	1	MAY 12	JUN 8	293	0.03	12323.	22842.	1.119	0.	0.59	0.	1.705	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 10	NOV 30	244	0.02	14046.	10236.	0.571	0.	0.29	0.	0.864	3.975
28	NAT10	50.0	43.0	0.140	1	MAR 17	APR 6	222	0.02	14047.	9357.	0.522	0.	0.29	0.	0.815	3.975
29	NAT11	50.0	43.0	0.140	1	FEB 11	MAR 2	189	0.02	14031.	8076.	0.450	0.	0.29	0.	0.743	3.975
30	NAT12	50.0	43.0	0.140	1	NOV 10	NOV 30	175	0.02	14037.	7369.	0.411	0.	0.29	0.	0.703	3.975
25	NAT7	25.0	22.3	0.110	1	DEC 15	DEC 28	160	0.02	14525.	3520.	0.203	0.	0.15	0.	0.349	3.975
26	NAT8	25.0	22.3	0.110	1	NOV 17	NOV 30	145	0.01	14551.	3184.	0.184	0.	0.15	0.	0.330	3.975
21	NAT3	25.0	22.3	0.110	1	DEC 15	DEC 28	131	0.01	14523.	2864.	0.165	0.	0.15	0.	0.311	3.975
22	NAT4	25.0	22.3	0.110	1	DEC 15	DEC 28	123	0.01	14532.	2709.	0.156	0.	0.15	0.	0.302	3.975
23	NAT5	25.0	22.3	0.110	1	NOV 17	NOV 30	115	0.01	14518.	2529.	0.146	0.	0.15	0.	0.292	3.975
24	NAT6	25.0	22.3	0.110	1	JUN 16	JUN 29	111	0.01	14518.	2457.	0.142	0.	0.15	0.	0.287	3.975
19	NAT1	25.0	22.3	0.110	1	DEC 15	DEC 28	108	0.01	14520.	2345.	0.135	0.	0.15	0.	0.281	3.975
20	NAT2	25.0	22.3	0.110	1	DEC 15	DEC 28	102	0.01	14525.	2235.	0.129	0.	0.15	0.	0.275	3.975
	TIEAID										31793.	0.191				0.191	6.000
	THERMAL TOTALS										29299662.	427.933	0.	65.19	0.	493.121	
	PRESENT VALUE OF TOTALS											403.710	0.	61.50	0.	465.209	

ANNUAL LOAD ENERGY (MWHRS) 34570062.

LIGHTING COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06
OPERATION + MAINTENANCE INFLATION FACTOR	0.03
PEAK LOAD (MW)	6000.00
THERMAL PEAK (MW)	5400.00
SPINNING RESERVE REQUIREMENT	0.
NIGHTLY PEAK LOAD ADDER (MW)	0.
MAXIMUM CAPACITY (MW)	6400.00
CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	APR 7	MAY 25	6320	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAR 3	APR 6	6437	0.73	9500.	3212343.	40.434	0.	5.22	0.	45.649	1.325
12	COAL8	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.76	9600.	2687006.	34.175	0.	4.64	0.	38.813	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26	JUN 29	6750	0.76	9600.	2677430.	34.054	0.	4.63	0.	38.684	1.325
17	OIL67	800.0	800.0	0.230	168	NOV 3	NOV 16	6505	0.72	9303.	5036322.	106.043	0.	8.33	0.	114.369	2.263
10	COAL7	300.0	300.0	0.100	3	FEB 11	MAR 9	7014	0.79	9704.	2076662.	26.700	0.	4.36	0.	31.060	1.325
7	COAL5	200.0	200.0	0.070	3	DEC 1	DEC 28	6805	0.75	10019.	1315448.	17.461	0.	3.19	0.	20.652	1.325
8	COAL6	200.0	200.0	0.070	3	OCT 6	NOV 2	6178	0.67	10022.	1182631.	15.703	0.	3.07	0.	18.771	1.325
3	COAL3	100.0	100.0	0.060	3	APR 7	APR 27	5829	0.63	12016.	557495.	8.876	0.	1.74	0.	10.616	1.325
4	COAL4	100.0	100.0	0.060	3	APR 28	MAY 18	5535	0.60	12019.	530038.	8.440	0.	1.71	0.	10.153	1.325
2	COAL2	100.0	100.0	0.060	3	NOV 10	NOV 30	5418	0.58	12032.	508397.	8.105	0.	1.69	0.	9.794	1.325
1	COAL1	100.0	100.0	0.060	3	NOV 10	NOV 30	5053	0.54	12025.	475366.	7.574	0.	1.66	0.	9.229	1.325
16	OIL66	600.0	600.0	0.220	2	NOV 17	DEC 21	4123	0.38	9443.	1990922.	42.552	0.	4.10	0.	46.650	2.263
15	OIL65	500.0	500.0	0.190	2	JAN 7	FEB 10	3254	0.27	9562.	1189425.	25.741	0.	3.57	0.	29.315	2.263
11	OIL64	300.0	300.0	0.100	2	MAR 10	APR 6	2137	0.19	9819.	497646.	11.060	0.	2.90	0.	13.956	2.263
9	OIL63	200.0	200.0	0.070	2	FEB 4	MAR 2	1383	0.13	10133.	224870.	5.157	0.	2.18	0.	7.336	2.263
5	OIL61	100.0	100.8	0.060	2	MAY 19	JUN 8	1029	0.10	12065.	88042.	2.404	0.	1.25	0.	3.655	2.263
6	OIL62	100.0	97.1	0.060	2	JUN 9	JUN 29	861	0.08	12095.	70863.	1.940	0.	1.23	0.	3.173	2.263
31	NAT13	100.0	85.0	0.150	1	JAN 7	FEB 3	687	0.06	12382.	52681.	2.593	0.	0.60	0.	3.188	3.975
32	NAT14	100.0	85.0	0.150	1	FEB 11	MAR 9	570	0.05	12316.	44735.	2.190	0.	0.59	0.	2.783	3.975
27	NAT9	50.0	43.0	0.140	1	DEC 8	DEC 28	491	0.05	14035.	20751.	1.158	0.	0.30	0.	1.454	3.975
28	NAT10	50.0	43.0	0.140	1	NOV 10	NOV 30	452	0.04	14039.	19169.	1.070	0.	0.30	0.	1.365	3.975
29	NAT11	50.0	43.0	0.140	1	OCT 13	NOV 2	403	0.04	14034.	16912.	0.943	0.	0.29	0.	1.238	3.975
30	NAT12	50.0	43.0	0.140	1	DEC 8	DEC 28	361	0.03	14050.	15150.	0.846	0.	0.29	0.	1.140	3.975
25	NAT7	25.0	22.2	0.110	1	DEC 15	DEC 28	325	0.03	14520.	7143.	0.412	0.	0.15	0.	0.560	3.975
26	NAT8	25.0	22.2	0.110	1	APR 7	APR 20	310	0.03	14527.	6807.	0.393	0.	0.15	0.	0.540	3.975
21	NAT3	25.0	22.2	0.110	1	DEC 15	DEC 28	291	0.03	14521.	6418.	0.370	0.	0.15	0.	0.517	3.975
22	NAT4	25.0	22.2	0.110	1	NOV 17	NOV 30	277	0.03	14528.	6054.	0.350	0.	0.15	0.	0.496	3.975
23	NAT5	25.0	22.2	0.110	1	DEC 15	DEC 28	250	0.03	14512.	5556.	0.320	0.	0.15	0.	0.467	3.975
24	NAT6	25.0	22.2	0.110	1	NOV 17	NOV 30	244	0.02	14520.	5396.	0.311	0.	0.15	0.	0.453	3.975
19	NAT1	25.0	22.2	0.110	1	DEC 15	DEC 28	235	0.02	14523.	5156.	0.298	0.	0.15	0.	0.444	3.975
20	NAT2	25.0	22.2	0.110	1	NOV 17	NOV 30	224	0.02	14512.	4945.	0.285	0.	0.15	0.	0.432	3.975
	TIEAID										75907.	0.455				0.455	6.000
	THERMAL TOTALS										29665404.	441.882	0.	65.39	0.	507.276	
	PRESENT VALUE OF TOTALS											416.869	0.	61.69	0.	478.562	

ANNUAL LOAD ENERGY (MWHRS) 34935804.

TELEVISION COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06
OPERATION + MAINTENANCE INFLATION FACTOR	0.03
PEAK LOAD (MW)	5922.00
THERMAL PEAK (MW)	5328.00

SPINNING RESERVE REQUIREMENT	0.
NIGHTLY PEAK LOAD ADDER (MW)	0.
MAXIMUM CAPACITY (MW)	6400.00
CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	APR 21	JUN 8	6318	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	NOV 3	DEC 7	6437	0.73	9500.	3216481.	40.485	0.	5.22	0.	45.703	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 24	DEC 28	6750	0.77	9600.	2694630.	34.271	0.	4.64	0.	38.916	1.325
13	COAL9	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.77	9599.	2691109.	34.226	0.	4.64	0.	38.867	1.325
17	OIL67	800.0	800.0	0.230	168	APR 7	APR 20	6505	0.72	9301.	5064276.	106.616	0.	8.35	0.	114.961	2.263
10	COAL7	300.0	300.0	0.100	3	JAN 7	FEB 3	6985	0.78	9706.	2058587.	26.474	0.	4.34	0.	30.817	1.325
7	COAL5	200.0	200.0	0.070	3	DEC 1	DEC 28	6692	0.74	10010.	1308013.	17.346	0.	3.18	0.	20.530	1.325
8	COAL6	200.0	200.0	0.070	3	MAR 10	APR 6	6409	0.70	10028.	1223139.	16.250	0.	3.11	0.	19.355	1.325
3	COAL3	100.0	100.0	0.060	3	JAN 7	JAN 27	5990	0.66	12013.	577986.	9.199	0.	1.76	0.	10.961	1.325
4	COAL4	100.0	100.0	0.060	3	JUN 9	JUN 29	5740	0.62	12022.	545809.	8.694	0.	1.73	0.	10.422	1.325
2	COAL2	100.0	100.0	0.060	3	JUN 9	JUN 29	5465	0.59	12023.	518744.	8.263	0.	1.70	0.	9.964	1.325
1	COAL1	100.0	100.0	0.060	3	JAN 7	JAN 27	5129	0.55	12026.	482456.	7.687	0.	1.66	0.	9.350	1.325
16	OIL66	600.0	599.8	0.220	2	MAR 3	APR 6	4305	0.40	9440.	2101337.	44.900	0.	4.17	0.	49.074	2.263
15	OIL65	500.0	499.8	0.190	2	JAN 28	MAR 2	3218	0.25	9578.	1118996.	24.258	0.	3.52	0.	27.774	2.263
11	OIL64	300.0	297.4	0.100	2	JUN 9	JUL 6	1951	0.17	9854.	435693.	9.717	0.	2.84	0.	12.556	2.263
9	OIL63	200.0	221.0	0.070	2	OCT 27	NOV 23	1242	0.11	10132.	200519.	4.599	0.	2.16	0.	6.755	2.263
5	OIL61	100.0	94.0	0.060	2	DEC 8	DEC 28	910	0.09	12079.	75357.	2.060	0.	1.24	0.	3.298	2.263
6	OIL62	100.0	94.0	0.060	2	FEB 18	MAR 9	707	0.07	12088.	59360.	1.624	0.	1.22	0.	2.845	2.263
31	NAT13	100.0	85.0	0.150	1	APR 7	MAY 4	590	0.05	12365.	45719.	2.247	0.	0.59	0.	2.840	3.975
32	NAT14	100.0	85.0	0.150	1	SEP 29	OCT 26	499	0.04	12366.	38371.	1.886	0.	0.59	0.	2.477	3.975
27	NAT9	50.0	43.0	0.140	1	JAN 7	JAN 27	406	0.04	14050.	17085.	0.954	0.	0.29	0.	1.249	3.975
28	NAT10	50.0	43.0	0.140	1	MAY 5	MAY 25	374	0.04	14063.	15562.	0.870	0.	0.29	0.	1.164	3.975
29	NAT11	50.0	43.0	0.140	1	FEB 4	FEB 24	312	0.03	14043.	13158.	0.734	0.	0.29	0.	1.028	3.975
30	NAT12	50.0	43.0	0.140	1	JUN 9	JUN 29	278	0.03	14031.	11703.	0.653	0.	0.29	0.	0.946	3.975
25	NAT7	25.0	22.2	0.110	1	MAY 5	MAY 18	264	0.03	14527.	5838.	0.337	0.	0.15	0.	0.484	3.975
26	NAT8	25.0	22.2	0.110	1	DEC 15	DEC 28	246	0.02	14525.	5456.	0.315	0.	0.15	0.	0.462	3.975
21	NAT3	25.0	22.2	0.110	1	DEC 8	DEC 21	235	0.02	14522.	5181.	0.299	0.	0.15	0.	0.445	3.975
22	NAT4	25.0	22.2	0.110	1	NOV 10	NOV 23	227	0.02	14525.	5016.	0.290	0.	0.15	0.	0.436	3.975
23	NAT5	25.0	22.2	0.110	1	JAN 7	JAN 20	214	0.02	14515.	4697.	0.271	0.	0.15	0.	0.417	3.975
24	NAT6	25.0	22.2	0.110	1	FEB 4	FEB 17	208	0.02	14542.	4501.	0.260	0.	0.15	0.	0.406	3.975
19	NAT1	25.0	22.2	0.110	1	NOV 10	NOV 23	190	0.02	14513.	4197.	0.242	0.	0.15	0.	0.388	3.975
20	NAT2	25.0	22.2	0.110	1	FEB 25	MAR 9	184	0.02	14527.	4016.	0.232	0.	0.15	0.	0.378	3.975
	TIEAID										56525.	0.339				0.339	6.000
	THERMAL TOTALS										29661228.	440.064	0.	65.41	0.	505.472	
	PRESENT VALUE OF TOTALS											415.155	0.	61.71	0.	476.860	

RANGES AND OVEN COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06
OPERATION + MAINTENANCE INFLATION FACTOR	0.03
PEAK LOAD (MW)	6000.00
THERMAL PEAK (MW)	5400.00

SPINNING RESERVE REQUIREMENT	0.
NIGHTLY PEAK LOAD ADDER (MW)	0.
MAXIMUM CAPACITY (MW)	6400.00
CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	APR 21	JUN 3	6318	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	NOV 3	DEC 7	6437	0.73	9500.	3212556.	40.436	0.	5.22	0.	45.652	1.325
12	COAL8	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.77	9600.	2691606.	34.233	0.	4.64	0.	38.875	1.325
13	COAL9	400.0	400.0	0.150	168	NOV 24	DEC 28	6750	0.76	9600.	2686819.	34.172	0.	4.64	0.	33.310	1.325
17	OIL67	800.0	800.0	0.230	168	APR 7	APR 20	6505	0.71	9304.	5008232.	105.465	0.	8.31	0.	113.771	2.263
10	COAL7	300.0	300.0	0.100	3	FEB 11	MAR 9	6373	0.76	9711.	2013028.	25.899	0.	4.30	0.	30.200	1.325
7	COAL5	200.0	200.0	0.070	3	MAR 10	APR 6	6640	0.74	10011.	1294918.	17.175	0.	3.17	0.	20.346	1.325
8	COAL6	200.0	200.0	0.070	3	FEB 4	MAR 2	6223	0.67	10031.	1132912.	15.721	0.	3.07	0.	18.789	1.325
3	COAL3	100.0	100.0	0.060	3	APR 7	APR 27	5929	0.65	12020.	567693.	9.041	0.	1.75	0.	10.792	1.325
4	COAL4	100.0	100.0	0.060	3	APR 28	MAY 18	5711	0.61	12041.	532592.	8.496	0.	1.71	0.	10.211	1.325
2	COAL2	100.0	100.0	0.060	3	JUN 9	JUN 29	5455	0.59	12033.	514296.	8.199	0.	1.70	0.	9.895	1.325
1	COAL1	100.0	100.0	0.060	3	DEC 8	DEC 28	5171	0.56	12023.	491261.	7.825	0.	1.67	0.	9.497	1.325
16	OIL66	600.0	600.0	0.220	2	MAR 3	APR 5	4139	0.39	9437.	2047205.	43.726	0.	4.14	0.	47.362	2.263
15	OIL65	500.0	500.0	0.190	2	JAN 7	FEB 10	3258	0.27	9559.	1139645.	25.739	0.	3.57	0.	29.312	2.263
11	OIL64	300.0	300.0	0.100	2	JUN 9	JUL 6	2125	0.19	9328.	487594.	10.847	0.	2.89	0.	13.733	2.263
9	OIL63	200.0	219.5	0.070	2	OCT 27	NOV 23	1372	0.13	10119.	224333.	5.133	0.	2.18	0.	7.317	2.263
5	OIL61	100.0	100.8	0.060	2	DEC 6	DEC 23	1013	0.10	12069.	35225.	2.323	0.	1.25	0.	3.576	2.263
6	OIL62	100.0	97.1	0.060	2	JUL 9	JUN 29	819	0.08	12034.	63274.	1.867	0.	1.23	0.	3.093	2.263
31	NAT13	100.0	35.0	0.150	1	SEP 29	OCT 25	661	0.06	12312.	51753.	2.533	0.	0.60	0.	3.128	3.975
32	NAT14	100.0	35.0	0.150	1	APR 26	MAY 25	549	0.05	12320.	42916.	2.101	0.	0.59	0.	2.694	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 10	NOV 30	475	0.05	14045.	19957.	1.116	0.	0.30	0.	1.412	3.975
28	NAT10	50.0	43.0	0.140	1	APR 7	APR 27	427	0.04	14043.	17995.	1.004	0.	0.30	0.	1.300	3.975
29	NAT11	50.0	43.0	0.140	1	DEC 8	DEC 28	359	0.04	14042.	15595.	0.870	0.	0.29	0.	1.165	3.975
30	NAT12	50.0	43.0	0.140	1	JAN 7	JAN 27	333	0.03	14044.	14053.	0.736	0.	0.29	0.	1.080	3.975
25	NAT7	25.0	22.3	0.110	1	FEB 16	MAR 2	300	0.03	14513.	6661.	0.334	0.	0.15	0.	0.531	3.975
26	NAT8	25.0	22.3	0.110	1	JUN 16	JUN 29	290	0.03	14527.	6337.	0.369	0.	0.15	0.	0.516	3.975
21	NAT3	25.0	22.3	0.110	1	FEB 11	FEB 24	275	0.03	14523.	6037.	0.349	0.	0.15	0.	0.495	3.975
22	NAT4	25.0	22.3	0.110	1	JUN 9	JUN 22	259	0.03	14537.	5652.	0.327	0.	0.15	0.	0.473	3.975
23	NAT5	25.0	22.3	0.110	1	OCT 6	OCT 19	235	0.02	14513.	5176.	0.299	0.	0.15	0.	0.445	3.975
24	NAT6	25.0	22.3	0.110	1	NOV 10	NOV 23	231	0.02	14522.	5049.	0.291	0.	0.15	0.	0.438	3.975
19	NAT1	25.0	22.3	0.110	1	NOV 10	NOV 23	219	0.02	14519.	4799.	0.277	0.	0.15	0.	0.423	3.975
20	NAT2	25.0	22.3	0.110	1	NOV 10	NOV 23	209	0.02	14515.	4620.	0.267	0.	0.15	0.	0.413	3.975
	TIEAID										33519.	0.399				0.399	6.000
	THERMAL TOTALS										29623140.	441.148	0.	55.37	0.	506.513	
	PRESENT VALUE OF TOTALS											416.177	0.	61.67	0.	477.842	

ANNUAL LOAD ENERGY (MWHRS) 34393640.

Arthur D Little, Inc.

AIR CONDITIONING COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE 0.06
OPERATION + MAINTENANCE INFLATION FACTOR 0.03
PEAK LOAD (MW) 5640.00
THERMAL PEAK (MW) 5040.00

SPINNING RESERVE REQUIREMENT 0.
NIGHTLY PEAK LOAD ADDER (MW) 0.
MAXIMUM CAPACITY (MW) 6400.00
CONTINUOUS CAPACITY (MW) 6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	APR 21	JUN 3	6318	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	NOV 3	DEC 7	6437	0.73	9500.	3208017.	40.379	0.	5.21	0.	45.591	1.325
12	COAL8	400.0	400.0	0.150	168	JAN 7	FEB 10	6750	0.76	9599.	2687738.	34.182	0.	4.64	0.	38.821	1.325
13	COAL9	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.76	9599.	2682418.	34.116	0.	4.63	0.	38.750	1.325
17	OIL67	800.0	800.0	0.230	168	APR 7	APR 20	6505	0.71	9304.	5011882.	105.538	0.	8.31	0.	113.847	2.263
10	COAL7	300.0	300.0	0.100	3	DEC 1	DEC 23	6674	0.74	9708.	1961517.	25.229	0.	4.25	0.	29.483	1.325
7	COAL5	200.0	200.0	0.070	3	NOV 3	NOV 30	6461	0.71	10017.	1253490.	16.635	0.	3.13	0.	19.768	1.325
8	COAL6	200.0	200.0	0.070	3	DEC 1	DEC 23	6091	0.67	10022.	1174526.	15.596	0.	3.06	0.	18.656	1.325
3	COAL3	100.0	100.0	0.060	3	MAR 31	APR 20	5875	0.65	12013.	570045.	9.073	0.	1.75	0.	10.827	1.325
4	COAL4	100.0	100.0	0.060	3	JUN 9	JUN 29	5683	0.62	12021.	546074.	8.697	0.	1.73	0.	10.426	1.325
2	COAL2	100.0	100.0	0.060	3	MAR 10	MAR 30	5565	0.61	12018.	534978.	8.518	0.	1.72	0.	10.236	1.325
1	COAL1	100.0	100.0	0.060	3	JUN 9	JUN 29	5332	0.58	12020.	509091.	8.108	0.	1.69	0.	9.798	1.325
16	OIL66	600.0	600.0	0.220	2	MAR 3	APR 6	4415	0.42	9431.	2232662.	47.660	0.	4.27	0.	51.925	2.263
15	OIL65	500.0	500.0	0.190	2	JUN 9	JUL 13	3434	0.27	9570.	1204630.	26.093	0.	3.59	0.	29.679	2.263
11	OIL64	300.0	303.1	0.100	2	FEB 11	MAR 9	2233	0.19	9860.	489813.	10.931	0.	2.89	0.	13.820	2.263
9	OIL63	200.0	186.0	0.070	2	FEB 4	MAR 2	1261	0.11	10150.	199784.	4.590	0.	2.16	0.	6.746	2.263
5	OIL61	100.0	94.0	0.060	2	APR 21	MAY 11	917	0.09	12091.	75710.	2.072	0.	1.24	0.	3.310	2.263
6	OIL62	100.0	94.0	0.060	2	DEC 8	DEC 28	716	0.07	12104.	58346.	1.598	0.	1.22	0.	2.819	2.263
31	NAT13	100.0	85.0	0.150	1	JAN 7	FEB 3	555	0.05	12349.	42814.	2.101	0.	0.59	0.	2.694	3.975
32	NAT14	100.0	85.0	0.150	1	OCT 6	NOV 2	468	0.04	12443.	35000.	1.731	0.	0.59	0.	2.321	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 10	NOV 30	374	0.04	14049.	15796.	0.882	0.	0.29	0.	1.177	3.975
28	NAT10	50.0	43.0	0.140	1	MAY 5	MAY 25	339	0.03	14055.	14164.	0.791	0.	0.29	0.	1.085	3.975
29	NAT11	50.0	43.0	0.140	1	MAR 10	MAR 30	282	0.03	14043.	11899.	0.664	0.	0.29	0.	0.958	3.975
30	NAT12	50.0	43.0	0.140	1	JUL 7	JUL 27	252	0.02	14053.	10574.	0.591	0.	0.29	0.	0.984	3.975
25	NAT7	25.0	22.3	0.110	1	NOV 10	NOV 23	229	0.02	14524.	5013.	0.289	0.	0.15	0.	0.436	3.975
26	NAT8	25.0	22.2	0.110	1	JUL 14	JUL 27	218	0.02	14522.	4755.	0.274	0.	0.15	0.	0.421	3.975
21	NAT3	25.0	22.3	0.110	1	JUL 14	JUL 27	207	0.02	14535.	4541.	0.262	0.	0.15	0.	0.409	3.975
22	NAT4	25.0	22.3	0.110	1	JUL 14	JUL 27	193	0.02	14537.	4205.	0.243	0.	0.15	0.	0.389	3.975
23	NAT5	25.0	22.3	0.110	1	JUL 14	JUL 27	177	0.02	14527.	3898.	0.225	0.	0.15	0.	0.371	3.975
24	NAT6	25.0	22.3	0.110	1	MAY 12	MAY 25	169	0.02	14542.	3680.	0.213	0.	0.15	0.	0.359	3.975
19	NAT1	25.0	22.3	0.110	1	JUL 14	JUL 27	151	0.02	14525.	3307.	0.191	0.	0.15	0.	0.337	3.975
20	NAT2	25.0	22.3	0.110	1	JUL 14	JUL 27	144	0.01	14531.	3139.	0.181	0.	0.15	0.	0.327	3.975
	TIEAID										39673.	0.238				0.238	6.000
	THERMAL TOTALS										29654892.	441.361	0.	65.41	0.	506.768	
	PRESENT VALUE OF TOTALS											416.378	0.	61.70	0.	478.083	

ANNUAL LOAD ENERGY (MWHRS) 34925292.

Arthur D Little, Inc.

CLOTHES DRYERS (AIR) COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06
OPERATION + MAINTENANCE INFLATION FACTOR	0.03
PEAK LOAD (MW)	6000.00
THERMAL PEAK (MW)	5400.00

SPINNING RESERVE REQUIREMENT	0.
NIGHTLY PEAK LOAD ADDER (MW)	0.
MAXIMUM CAPACITY (MW)	6400.00
CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	APR 21	JUN 8	6318	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	OCT 27	NOV 30	6436	0.73	9500.	3211555.	40.424	0.	5.21	0.	45.633	1.325
12	COAL8	400.0	400.0	0.150	168	JAN 28	MAR 2	6751	0.77	9600.	2696278.	34.293	0.	4.65	0.	38.938	1.325
13	COAL9	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.77	9599.	2691494.	34.231	0.	4.64	0.	38.873	1.325
17	OIL67	800.0	800.0	0.230	168	APR 7	APR 20	6505	0.72	9302.	5045292.	106.227	0.	8.33	0.	114.559	2.263
10	COAL7	300.0	300.0	0.100	3	JAN 7	FEB 3	6772	0.75	9710.	1982308.	25.501	0.	4.27	0.	29.774	1.325
7	COAL5	200.0	200.0	0.070	3	FEB 25	MAR 23	6495	0.72	10006.	1272340.	16.874	0.	3.15	0.	20.025	1.325
8	COAL6	200.0	200.0	0.070	3	MAR 24	APR 20	6220	0.63	10029.	1136614.	15.767	0.	3.07	0.	18.838	1.325
3	COAL3	100.0	100.0	0.060	3	APR 21	MAY 11	5877	0.65	12003.	567744.	9.033	0.	1.75	0.	10.784	1.325
4	COAL4	100.0	100.0	0.060	3	DEC 8	DEC 23	5692	0.62	12016.	546469.	8.700	0.	1.73	0.	10.429	1.325
2	COAL2	100.0	100.0	0.060	3	JUN 9	JUN 29	5451	0.59	12016.	522115.	8.312	0.	1.70	0.	10.016	1.325
1	COAL1	100.0	100.0	0.060	3	JAN 7	JAN 27	5160	0.56	12017.	493357.	7.863	0.	1.67	0.	9.538	1.325
16	OIL66	600.0	600.0	0.220	2	MAR 3	APR 6	4330	0.40	9439.	2124630.	45.390	0.	4.19	0.	49.581	2.263
15	OIL65	500.0	500.0	0.190	2	NOV 24	DEC 23	3237	0.26	9530.	1153185.	25.094	0.	3.54	0.	28.548	2.263
11	OIL64	300.0	300.0	0.100	2	JUN 9	JUL 6	1932	0.17	9348.	446190.	9.945	0.	2.85	0.	12.794	2.263
9	OIL63	200.0	211.7	0.070	2	NOV 10	DEC 7	1240	0.12	10126.	203397.	4.661	0.	2.16	0.	6.821	2.263
5	OIL61	100.0	100.8	0.060	2	JAN 7	JAN 27	913	0.09	12064.	77269.	2.110	0.	1.24	0.	3.350	2.263
6	OIL62	100.0	97.1	0.060	2	FEB 4	FEB 24	737	0.07	12088.	61377.	1.679	0.	1.22	0.	2.903	2.263
31	NAT13	100.0	85.0	0.150	1	SEP 29	OCT 26	583	0.05	12299.	45898.	2.244	0.	0.59	0.	2.837	3.975
32	NAT14	100.0	85.0	0.150	1	APR 28	MAY 25	511	0.05	12333.	39841.	1.953	0.	0.59	0.	2.545	3.975
27	NAT9	50.0	43.0	0.140	1	JUN 9	JUN 29	423	0.04	14032.	17831.	0.997	0.	0.30	0.	1.292	3.975
28	NAT10	50.0	43.0	0.140	1	JUN 9	JUN 29	393	0.04	14057.	16391.	0.916	0.	0.29	0.	1.211	3.975
29	NAT11	50.0	43.0	0.140	1	NOV 3	NOV 23	346	0.03	14052.	14447.	0.807	0.	0.29	0.	1.101	3.975
30	NAT12	50.0	43.0	0.140	1	DEC 8	DEC 28	289	0.03	14043.	12163.	0.679	0.	0.29	0.	0.972	3.975
25	NAT7	25.0	22.3	0.110	1	JUN 9	JUN 22	256	0.03	14521.	5539.	0.325	0.	0.15	0.	0.472	3.975
26	NAT8	25.0	22.3	0.110	1	OCT 6	OCT 19	249	0.02	14521.	5484.	0.317	0.	0.15	0.	0.463	3.975
21	NAT3	25.0	22.3	0.110	1	MAY 12	MAY 25	241	0.02	14517.	5305.	0.306	0.	0.15	0.	0.453	3.975
22	NAT4	25.0	22.3	0.110	1	FEB 18	MAR 2	230	0.02	14518.	5093.	0.294	0.	0.15	0.	0.440	3.975
23	NAT5	25.0	22.3	0.110	1	JAN 7	JAN 20	220	0.02	14520.	4839.	0.279	0.	0.15	0.	0.426	3.975
24	NAT6	25.0	22.3	0.110	1	FEB 4	FEB 17	211	0.02	14519.	4663.	0.269	0.	0.15	0.	0.415	3.975
19	NAT1	25.0	22.3	0.110	1	NOV 10	NOV 23	205	0.02	14523.	4482.	0.259	0.	0.15	0.	0.405	3.975
20	NAT2	25.0	22.3	0.110	1	NOV 10	NOV 23	194	0.02	14513.	4281.	0.247	0.	0.15	0.	0.393	3.975
	TIEAID										63705.	0.382				0.382	6.000
	THERMAL TOTALS										29584440.	439.758	0.	65.32	0.	505.080	
	PRESENT VALUE OF TOTALS											414.866	0.	61.62	0.	476.491	

ANNUAL LOAD ENERGY (MWHRS) 34854340.

Arthur D Little, Inc.

DISHWASHERS (HEATERS) COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06
OPERATION + MAINTENANCE INFLATION FACTOR	0.03
PEAK LOAD (MW)	6000.00
THERMAL PEAK (MW)	5400.00
SPINNING RESERVE REQUIREMENT	0.
NIGHTLY PEAK LOAD ADDER (MW)	0.
MAXIMUM CAPACITY (MW)	6400.00
CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	APR 21	JUN 3	6318	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAR 3	APR 6	6437	0.73	9500.	3210724.	40.413	0.	5.21	0.	45.627	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 24	DEC 23	6750	0.77	9599.	2692995.	34.250	0.	4.64	0.	38.893	1.325
13	COAL9	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.77	9599.	2639134.	34.201	0.	4.64	0.	38.841	1.325
17	OIL67	800.0	800.0	0.230	168	APR 7	APR 20	6505	0.71	9303.	5016693.	105.635	0.	8.31	0.	113.948	2.263
10	COAL7	300.0	300.0	0.100	3	FEB 11	MAR 9	6600	0.73	9712.	1921630.	24.726	0.	4.22	0.	28.942	1.325
7	COAL5	200.0	200.0	0.070	3	MAR 10	APR 6	6191	0.68	10018.	1198245.	15.903	0.	3.08	0.	18.986	1.325
8	COAL6	200.0	200.0	0.070	3	FEB 4	MAR 2	5982	0.64	10041.	1130230.	15.035	0.	3.02	0.	18.054	1.325
3	COAL3	100.0	100.0	0.060	3	APR 7	APR 27	5652	0.63	12008.	552134.	8.734	0.	1.74	0.	10.519	1.325
4	COAL4	100.0	100.0	0.060	3	APR 28	MAY 18	5450	0.60	12017.	525155.	8.361	0.	1.71	0.	10.068	1.325
2	COAL2	100.0	100.0	0.060	3	OCT 13	NOV 2	5253	0.58	12013.	507352.	8.083	0.	1.69	0.	9.772	1.325
1	COAL1	100.0	100.0	0.060	3	JUN 9	JUN 29	5199	0.57	12020.	498289.	7.935	0.	1.68	0.	9.614	1.325
16	OIL66	600.0	600.0	0.220	2	NOV 3	DEC 7	4242	0.41	9431.	2158741.	46.073	0.	4.21	0.	50.292	2.263
15	OIL65	500.0	500.0	0.190	2	JAN 7	FEB 10	3508	0.29	9561.	1277274.	27.641	0.	3.64	0.	31.286	2.263
11	OIL64	300.0	300.0	0.100	2	JUN 9	JUL 6	2293	0.20	9841.	521446.	11.615	0.	2.92	0.	14.533	2.263
9	OIL63	200.0	211.1	0.070	2	DEC 1	DEC 23	1428	0.14	10091.	239736.	5.476	0.	2.19	0.	7.669	2.263
5	OIL61	100.0	100.3	0.060	2	JUN 9	JUN 29	1087	0.10	12068.	91444.	2.498	0.	1.25	0.	3.752	2.263
6	OIL62	100.0	97.1	0.060	2	DEC 8	DEC 28	876	0.08	12060.	74650.	2.038	0.	1.24	0.	3.275	2.263
31	NAT13	100.0	85.0	0.150	1	JAN 7	FEB 3	705	0.06	12298.	55800.	2.728	0.	0.60	0.	3.324	3.975
32	NAT14	100.0	85.0	0.150	1	OCT 27	NOV 23	630	0.06	12311.	49272.	2.411	0.	0.59	0.	3.005	3.975
27	NAT9	50.0	43.0	0.140	1	FEB 11	MAR 2	529	0.05	14044.	22205.	1.239	0.	0.30	0.	1.536	3.975
28	NAT10	50.0	43.0	0.140	1	MAR 10	MAR 30	483	0.05	14050.	20283.	1.133	0.	0.30	0.	1.429	3.975
29	NAT11	50.0	43.0	0.140	1	SEP 29	OCT 19	419	0.04	14043.	17613.	0.983	0.	0.30	0.	1.273	3.975
30	NAT12	50.0	43.0	0.140	1	MAY 5	MAY 25	373	0.04	14051.	15612.	0.872	0.	0.29	0.	1.166	3.975
25	NAT7	25.0	22.3	0.110	1	SEP 29	OCT 12	327	0.03	14522.	7190.	0.415	0.	0.15	0.	0.562	3.975
26	NAT8	25.0	22.3	0.110	1	MAR 24	APR 6	310	0.03	14519.	6901.	0.398	0.	0.15	0.	0.545	3.975
21	NAT3	25.0	22.3	0.110	1	NOV 10	NOV 23	300	0.03	14516.	6624.	0.382	0.	0.15	0.	0.529	3.975
22	NAT4	25.0	22.3	0.110	1	FEB 11	FEB 24	287	0.03	14522.	6330.	0.365	0.	0.15	0.	0.512	3.975
23	NAT5	25.0	22.3	0.110	1	MAR 31	APR 13	275	0.03	14513.	6059.	0.349	0.	0.15	0.	0.496	3.975
24	NAT6	25.0	22.3	0.110	1	FEB 18	MAR 2	264	0.03	14520.	5839.	0.337	0.	0.15	0.	0.484	3.975
19	NAT1	25.0	22.3	0.110	1	NOV 10	NOV 23	254	0.03	14519.	5596.	0.323	0.	0.15	0.	0.470	3.975
20	NAT2	25.0	22.3	0.110	1	NOV 10	NOV 23	243	0.02	14524.	5360.	0.309	0.	0.15	0.	0.456	3.975
	TIEAID										78058.	0.468				0.468	6.000
	THERMAL TOTALS										29666880.	444.854	0.	65.34	0.	510.195	
	PRESENT VALUE OF TOTALS											419.674	0.	61.64	0.	481.316	

Arthur D Little, Inc.

CLOTHES DRYERS (MOTORS) COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	6000.00	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5400.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	300.0	0.170	168	APR 21	JUN 3	6318	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	NOV 3	DEC 7	6437	0.73	9500.	3205259.	40.345	0.	5.21	0.	45.555	1.325
12	COAL8	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.77	9599.	2690325.	34.215	0.	4.64	0.	38.856	1.325
13	COAL9	400.0	400.0	0.150	168	NOV 24	DEC 28	6750	0.76	9599.	2683544.	34.129	0.	4.64	0.	38.764	1.325
17	OIL67	800.0	800.0	0.230	168	APR 7	APR 20	6505	0.71	9304.	4934051.	104.960	0.	8.29	0.	113.250	2.263
10	COAL7	300.0	300.0	0.100	3	JAN 7	FEB 3	6549	0.72	9712.	1908366.	24.561	0.	4.20	0.	28.766	1.325
7	COAL5	200.0	200.0	0.070	3	OCT 27	NOV 23	6122	0.68	10015.	1186673.	15.746	0.	3.07	0.	18.817	1.325
8	COAL6	200.0	200.0	0.070	3	MAR 3	MAR 30	5860	0.64	10026.	1126319.	14.961	0.	3.02	0.	17.976	1.325
3	COAL3	100.0	100.0	0.060	3	JUN 9	JUN 29	5668	0.63	12009.	652003.	8.783	0.	1.74	0.	10.513	1.325
4	COAL4	100.0	100.0	0.060	3	APR 28	MAY 18	5418	0.60	12018.	622350.	8.325	0.	1.70	0.	10.030	1.325
2	COAL2	100.0	100.0	0.060	3	JAN 7	JAN 27	5252	0.58	12014.	507739.	8.083	0.	1.69	0.	9.772	1.325
1	COAL1	100.0	100.0	0.060	3	DEC 8	DEC 28	5073	0.55	12020.	435117.	7.725	0.	1.67	0.	9.391	1.325
16	OIL66	600.0	600.0	0.220	2	MAR 3	APR 6	4184	0.41	9427.	2151623.	45.910	0.	4.21	0.	50.119	2.263
15	OIL65	500.0	500.0	0.190	2	JAN 28	MAR 2	3507	0.29	9559.	1233511.	27.769	0.	3.65	0.	31.419	2.263
11	OIL64	300.0	300.0	0.100	2	JUN 9	JUL 6	2307	0.20	9830.	528300.	11.754	0.	2.92	0.	14.673	2.263
9	OIL63	200.0	212.1	0.070	2	MAR 31	APR 27	1503	0.14	10119.	246392.	5.643	0.	2.20	0.	7.843	2.263
5	OIL61	100.0	100.8	0.060	2	DEC 8	DEC 28	1124	0.11	12072.	94777.	2.590	0.	1.26	0.	3.848	2.263
6	OIL62	100.0	97.1	0.060	2	JAN 7	JAN 27	915	0.09	12074.	76861.	2.101	0.	1.24	0.	3.340	2.263
31	NAT13	100.0	85.0	0.150	1	SEP 29	OCT 26	716	0.06	12304.	56190.	2.748	0.	0.60	0.	3.345	3.975
32	NAT14	100.0	85.0	0.150	1	APR 28	MAY 25	615	0.05	12323.	48168.	2.359	0.	0.59	0.	2.954	3.975
27	NAT9	50.0	43.0	0.140	1	JUN 9	JUN 29	527	0.05	14045.	22120.	1.235	0.	0.30	0.	1.531	3.975
23	NAT10	50.0	43.0	0.140	1	JUN 9	JUN 29	472	0.05	14045.	19904.	1.111	0.	0.30	0.	1.407	3.975
29	NAT11	50.0	43.0	0.140	1	NOV 10	NOV 30	423	0.04	14038.	17374.	0.997	0.	0.30	0.	1.293	3.975
30	NAT12	50.0	43.0	0.140	1	FEB 11	MAR 2	377	0.04	14046.	15856.	0.885	0.	0.29	0.	1.180	3.975
25	NAT7	25.0	22.3	0.110	1	JUN 9	JUN 22	324	0.03	14517.	7153.	0.413	0.	0.15	0.	0.560	3.975
26	NAT8	25.0	22.3	0.110	1	OCT 6	OCT 19	318	0.03	14524.	6956.	0.402	0.	0.15	0.	0.549	3.975
21	NAT3	25.0	22.3	0.110	1	DEC 8	DEC 21	299	0.03	14522.	6622.	0.382	0.	0.15	0.	0.529	3.975
22	NAT4	25.0	22.3	0.110	1	DEC 15	DEC 28	287	0.03	14528.	6312.	0.365	0.	0.15	0.	0.511	3.975
23	NAT5	25.0	22.3	0.110	1	FEB 25	MAR 9	265	0.03	14515.	5883.	0.339	0.	0.15	0.	0.486	3.975
24	NAT6	25.0	22.3	0.110	1	JAN 7	JAN 20	259	0.03	14521.	5699.	0.329	0.	0.15	0.	0.476	3.975
19	NAT1	25.0	22.3	0.110	1	NOV 10	NOV 23	245	0.02	14518.	5440.	0.314	0.	0.15	0.	0.460	3.975
20	NAT2	25.0	22.3	0.110	1	NOV 10	NOV 23	238	0.02	14513.	5253.	0.303	0.	0.15	0.	0.449	3.975
	TIEAID										76865.	0.461				0.461	6.000
	THERMAL TOTALS										29592270.	443.711	0.	65.28	0.	508.993	
	PRESENT VALUE OF TOTALS											418.595	0.	61.59	0.	480.182	

ANNUAL LOAD ENERGY (MWHRS) 34862670.

Arthur D Little, Inc.

CLOTHES WASHERS (MOTORS) COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	6000.00	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5400.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
13	NUC1	800.0	800.0	0.170	168	APR 21	JUN 8	6318	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	NOV 3	DEC 7	6437	0.73	9500.	3206488.	40.360	0.	5.21	0.	45.571	1.325
12	COAL8	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.77	9599.	2690835.	34.222	0.	4.64	0.	38.863	1.325
13	COAL9	400.0	400.0	0.150	168	NOV 24	DEC 28	6750	0.76	9599.	2682360.	34.113	0.	4.63	0.	38.747	1.325
17	OIL67	800.0	800.0	0.230	168	APR 7	APR 20	6505	0.71	9304.	4939290.	105.070	0.	8.29	0.	113.363	2.263
10	COAL7	300.0	300.0	0.100	3	JAN 7	FEB 3	6472	0.71	9711.	1833863.	24.239	0.	4.18	0.	28.421	1.325
7	COAL5	200.0	200.0	0.070	3	MAR 3	MAR 30	6184	0.68	10014.	1201723.	15.944	0.	3.09	0.	19.029	1.325
8	COAL6	200.0	200.0	0.070	3	OCT 27	NOV 23	5815	0.63	10031.	1111633.	14.773	0.	3.00	0.	17.775	1.325
3	COAL3	100.0	100.0	0.060	3	JUN 9	JUN 29	5669	0.63	12008.	552327.	8.787	0.	1.74	0.	10.522	1.325
4	COAL4	100.0	100.0	0.060	3	APR 28	MAY 18	5406	0.60	12016.	522901.	8.325	0.	1.70	0.	10.029	1.325
2	COAL2	100.0	100.0	0.060	3	JAN 7	JAN 27	5258	0.58	12011.	509759.	8.112	0.	1.69	0.	9.803	1.325
1	COAL1	100.0	100.0	0.060	3	DEC 8	DEC 28	5088	0.56	12017.	488459.	7.777	0.	1.67	0.	9.446	1.325
16	OIL66	600.0	600.0	0.220	2	MAR 3	APR 5	4206	0.41	9427.	2178489.	46.480	0.	4.23	0.	50.708	2.263
15	OIL65	500.0	500.0	0.190	2	JAN 28	MAR 2	3544	0.30	9558.	1300632.	28.137	0.	3.66	0.	31.800	2.263
11	OIL64	300.0	300.0	0.100	2	JUN 9	JUL 6	2358	0.21	9826.	542309.	12.060	0.	2.94	0.	14.998	2.263
9	OIL63	200.0	212.0	0.070	2	MAR 31	APR 27	1557	0.14	10125.	253846.	5.817	0.	2.21	0.	8.023	2.263
5	OIL61	100.0	100.8	0.060	2	DEC 8	DEC 28	1153	0.11	12068.	97750.	2.670	0.	1.26	0.	3.931	2.263
6	OIL62	100.0	97.1	0.060	2	JAN 7	JAN 27	934	0.09	12072.	78879.	2.155	0.	1.24	0.	3.397	2.263
31	NAT13	100.0	85.0	0.150	1	SEP 29	OCT 26	762	0.07	12366.	58703.	2.885	0.	0.60	0.	3.483	3.975
32	NAT14	100.0	85.0	0.150	1	APR 28	MAY 25	637	0.06	12337.	49639.	2.434	0.	0.59	0.	3.029	3.975
27	NAT9	50.0	43.0	0.140	1	JUN 9	JUN 29	544	0.05	14042.	22935.	1.280	0.	0.30	0.	1.577	3.975
28	NAT10	50.0	43.0	0.140	1	JUN 9	JUN 29	493	0.05	14047.	20741.	1.158	0.	0.30	0.	1.454	3.975
29	NAT11	50.0	43.0	0.140	1	NOV 10	NOV 30	437	0.04	14039.	18441.	1.029	0.	0.30	0.	1.324	3.975
30	NAT12	50.0	43.0	0.140	1	FEB 11	MAR 2	386	0.04	14037.	16271.	0.908	0.	0.29	0.	1.203	3.975
25	NAT7	25.0	22.3	0.110	1	OCT 6	OCT 19	355	0.04	14528.	7810.	0.451	0.	0.15	0.	0.598	3.975
26	NAT8	25.0	22.3	0.110	1	NOV 10	NOV 23	336	0.03	14529.	7346.	0.424	0.	0.15	0.	0.571	3.975
21	NAT3	25.0	22.3	0.110	1	DEC 8	DEC 21	312	0.03	14523.	6835.	0.397	0.	0.15	0.	0.544	3.975
22	NAT4	25.0	22.3	0.110	1	DEC 15	DEC 28	298	0.03	14522.	6539.	0.377	0.	0.15	0.	0.524	3.975
23	NAT5	25.0	22.3	0.110	1	JAN 7	JAN 20	273	0.03	14515.	6051.	0.349	0.	0.15	0.	0.496	3.975
24	NAT6	25.0	22.3	0.110	1	JUN 9	JUN 22	265	0.03	14520.	5820.	0.336	0.	0.15	0.	0.483	3.975
19	NAT1	25.0	22.3	0.110	1	NOV 10	NOV 23	255	0.03	14519.	5606.	0.323	0.	0.15	0.	0.470	3.975
20	NAT2	25.0	22.3	0.110	1	NOV 10	NOV 23	245	0.02	14514.	5409.	0.312	0.	0.15	0.	0.459	3.975
	TIEAID										80168.	0.481				0.481	6.000
THERMAL TOTALS											29661624.	445.655	0.	65.33	0.	510.985	
PRESENT VALUE OF TOTALS												420.429	0.	61.63	0.	482.061	

DISHWASHERS (MOTORS) COST CASE FOR SUMMER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06
OPERATION + MAINTENANCE INFLATION FACTOR	0.03
PEAK LOAD (MW)	6000.00
THERMAL PEAK (MW)	5400.00

SPINNING RESERVE REQUIREMENT	0.
NIGHTLY PEAK LOAD ADDER (MW)	0.
MAXIMUM CAPACITY (MW)	6400.00
CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	APR 21	JUN 8	6318	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAR 3	APR 6	6437	0.73	9500.	3208890.	40.391	0.	5.21	0.	45.603	1.325
12	COAL8	400.0	400.0	0.150	168	OCT 6	NOV 9	6750	0.77	9599.	2688109.	34.188	0.	4.64	0.	38.827	1.325
13	COAL9	400.0	400.0	0.150	168	NOV 24	DEC 28	6750	0.76	9600.	2679336.	34.077	0.	4.63	0.	38.709	1.325
17	OIL67	800.0	800.0	0.230	168	APR 7	APR 20	6505	0.71	9305.	4986202.	105.011	0.	8.29	0.	113.302	2.263
10	COAL7	300.0	300.0	0.100	3	FEB 11	MAR 9	6460	0.71	9713.	1875965.	24.142	0.	4.17	0.	28.316	1.325
7	COAL5	200.0	200.0	0.070	3	MAR 10	APR 6	6088	0.67	10017.	1178656.	15.643	0.	3.06	0.	18.707	1.325
8	COAL6	200.0	200.0	0.070	3	FEB 4	MAR 2	5782	0.63	10026.	1110960.	14.757	0.	3.00	0.	17.758	1.325
3	COAL3	100.0	100.0	0.060	3	DEC 8	DEC 28	5610	0.62	12008.	547117.	8.704	0.	1.73	0.	10.434	1.325
4	COAL4	100.0	100.0	0.060	3	MAY 5	MAY 25	5384	0.59	12017.	520407.	8.285	0.	1.70	0.	9.988	1.325
2	COAL2	100.0	100.0	0.060	3	JUN 9	JUN 29	5281	0.58	12014.	510294.	8.122	0.	1.69	0.	9.814	1.325
1	COAL1	100.0	100.0	0.060	3	DEC 8	DEC 28	5095	0.55	12022.	487437.	7.764	0.	1.67	0.	9.431	1.325
16	OIL66	600.0	600.0	0.220	2	NOV 3	DEC 7	4205	0.41	9427.	2182835.	46.575	0.	4.23	0.	50.806	2.263
15	OIL65	500.0	500.0	0.190	2	JAN 7	FEB 10	3568	0.30	9554.	1325092.	28.653	0.	3.68	0.	32.337	2.263
11	OIL64	300.0	300.0	0.100	2	JUN 9	JUL 6	2395	0.21	9828.	550954.	12.255	0.	2.95	0.	15.200	2.263
9	OIL63	200.0	212.0	0.070	2	APR 7	MAY 4	1559	0.15	10111.	257109.	5.884	0.	2.21	0.	8.093	2.263
5	OIL61	100.0	100.8	0.060	2	OCT 13	NOV 2	1171	0.11	12071.	98540.	2.692	0.	1.26	0.	3.954	2.263
6	OIL62	100.0	97.1	0.060	2	JUN 9	JUN 29	939	0.09	12066.	79815.	2.180	0.	1.24	0.	3.422	2.263
31	NAT13	100.0	85.0	0.150	1	MAR 10	APR 6	782	0.07	12327.	60740.	2.976	0.	0.60	0.	3.574	3.975
32	NAT14	100.0	85.0	0.150	1	OCT 27	NOV 23	648	0.06	12337.	50274.	2.465	0.	0.59	0.	3.060	3.975
27	NAT9	50.0	43.0	0.140	1	DEC 8	DEC 28	542	0.05	14039.	22898.	1.278	0.	0.30	0.	1.574	3.975
28	NAT10	50.0	43.0	0.140	1	JAN 7	JAN 27	502	0.05	14045.	21073.	1.176	0.	0.30	0.	1.473	3.975
29	NAT11	50.0	43.0	0.140	1	FEB 11	MAR 2	433	0.04	14035.	18380.	1.025	0.	0.30	0.	1.321	3.975
30	NAT12	50.0	43.0	0.140	1	OCT 6	OCT 26	394	0.04	14035.	16612.	0.927	0.	0.29	0.	1.222	3.975
25	NAT7	25.0	22.2	0.110	1	MAY 12	MAY 25	361	0.04	14518.	7963.	0.460	0.	0.15	0.	0.607	3.975
26	NAT8	25.0	22.2	0.110	1	DEC 8	DEC 21	343	0.03	14523.	7547.	0.436	0.	0.15	0.	0.583	3.975
21	NAT3	25.0	22.2	0.110	1	NOV 10	NOV 23	333	0.03	14528.	7305.	0.422	0.	0.15	0.	0.569	3.975
22	NAT4	25.0	22.2	0.110	1	NOV 10	NOV 23	313	0.03	14534.	6854.	0.396	0.	0.15	0.	0.543	3.975
23	NAT5	25.0	22.2	0.110	1	MAY 5	MAY 18	283	0.03	14520.	6206.	0.358	0.	0.15	0.	0.505	3.975
24	NAT6	25.0	22.2	0.110	1	JAN 21	FEB 3	270	0.03	14520.	5934.	0.342	0.	0.15	0.	0.489	3.975
19	NAT1	25.0	22.2	0.110	1	NOV 10	NOV 23	258	0.03	14524.	5683.	0.328	0.	0.15	0.	0.475	3.975
20	NAT2	25.0	22.2	0.110	1	NOV 10	NOV 23	247	0.02	14516.	5415.	0.312	0.	0.15	0.	0.459	3.975
	TIEAID										80661.	0.484				0.484	6.000
	THERMAL TOTALS										29662974.	446.177	0.	65.32	0.	511.501	
	PRESENT VALUE OF TOTALS											420.922	0.	61.63	0.	482.548	

SATURDAY LOAD MODEL FOR A WINTER PEAKING UTILITY

Fraction of Annual Peak Load Energy by Hour*

Time Period**	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
0	0.664	0.660	0.656	0.500	0.475	0.420	0.418	0.420	0.430	0.430	0.465	0.525
1	0.639	0.625	0.623	0.475	0.475	0.415	0.377	0.410	0.420	0.425	0.475	0.520
2	0.623	0.600	0.600	0.460	0.460	0.410	0.369	0.400	0.400	0.418	0.460	0.513
3	0.623	0.600	0.595	0.450	0.455	0.415	0.361	0.395	0.405	0.415	0.450	0.508
4	0.631	0.610	0.590	0.450	0.450	0.420	0.369	0.400	0.415	0.421	0.435	0.513
5	0.639	0.640	0.610	0.495	0.460	0.435	0.377	0.410	0.420	0.435	0.450	0.525
6	0.680	0.655	0.620	0.510	0.475	0.455	0.426	0.435	0.455	0.460	0.475	0.540
7	0.762	0.710	0.635	0.525	0.498	0.495	0.533	0.460	0.475	0.485	0.510	0.565
8	0.828	0.775	0.660	0.575	0.513	0.530	0.574	0.485	0.500	0.525	0.525	0.600
9	0.852	0.825	0.655	0.630	0.550	0.525	0.590	0.500	0.525	0.560	0.530	0.610
10	0.861	0.850	0.670	0.665	0.580	0.500	0.598	0.515	0.525	0.610	0.545	0.610
11	0.861	0.825	0.665	0.670	0.595	0.500	0.598	0.505	0.530	0.635	0.545	0.625
12	0.844	0.845	0.640	0.700	0.595	0.525	0.582	0.520	0.535	0.640	0.550	0.610
13	0.820	0.876	0.630	0.710	0.620	0.530	0.590	0.515	0.540	0.650	0.550	0.615
14	0.795	0.815	0.615	0.690	0.645	0.510	0.574	0.510	0.550	0.656	0.535	0.630
15	0.795	0.790	0.600	0.680	0.640	0.515	0.566	0.515	0.550	0.670	0.530	0.645
16	0.836	0.790	0.610	0.715	0.640	0.535	0.557	0.540	0.575	0.690	0.555	0.695
17	0.926	0.845	0.650	0.720	0.675	0.560	0.566	0.585	0.610	0.710	0.625	0.705
18	0.926	0.890	0.685	0.705	0.680	0.595	0.541	0.610	0.635	0.735	0.685	0.725
19	0.918	0.825	0.690	0.683	0.680	0.600	0.533	0.600	0.630	0.740	0.710	0.725
20	0.902	0.785	0.665	0.650	0.650	0.580	0.525	0.585	0.605	0.725	0.695	0.695
21	0.844	0.760	0.650	0.625	0.610	0.545	0.516	0.560	0.595	0.685	0.650	0.650
22	0.787	0.735	0.650	0.585	0.585	0.520	0.508	0.545	0.565	0.620	0.595	0.595
23	0.713	0.700	0.660	0.550	0.545	0.475	0.492	0.490	0.500	0.560	0.515	0.560

*1.000 = 6100 megawatts

**Load for 1 hour period following time indicated; 0 hour is midnight

SUNDAY LOAD MODEL FOR A WINTER PEAKING UTILITY

Fraction of Annual Peak Load Energy by Hour*

Time Period**	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
0	0.655	0.678	0.670	0.485	0.470	0.415	0.415	0.415	0.425	0.425	0.455	0.530
1	0.630	0.633	0.640	0.470	0.470	0.410	0.375	0.410	0.420	0.425	0.465	0.530
2	0.645	0.624	0.625	0.460	0.450	0.420	0.365	0.395	0.405	0.410	0.450	0.510
3	0.645	0.615	0.615	0.465	0.435	0.430	0.365	0.390	0.415	0.415	0.430	0.505
4	0.671	0.607	0.610	0.470	0.450	0.420	0.380	0.395	0.420	0.430	0.450	0.515
5	0.679	0.633	0.610	0.490	0.465	0.435	0.385	0.405	0.430	0.450	0.465	0.520
6	0.660	0.645	0.615	0.505	0.480	0.450	0.435	0.430	0.445	0.475	0.470	0.550
7	0.720	0.695	0.640	0.515	0.485	0.475	0.540	0.435	0.455	0.495	0.495	0.580
8	0.800	0.755	0.655	0.550	0.500	0.495	0.580	0.465	0.490	0.525	0.550	0.595
9	0.820	0.800	0.645	0.600	0.530	0.510	0.600	0.485	0.510	0.540	0.575	0.595
10	0.840	0.800	0.640	0.625	0.545	0.535	0.604	0.490	0.525	0.575	0.560	0.610
11	0.840	0.815	0.640	0.640	0.585	0.510	0.604	0.490	0.525	0.610	0.565	0.615
12	0.850	0.815	0.655	0.655	0.600	0.535	0.600	0.515	0.540	0.625	0.575	0.620
13	0.830	0.835	0.660	0.685	0.625	0.525	0.600	0.520	0.545	0.630	0.560	0.625
14	0.800	0.800	0.650	0.675	0.630	0.510	0.580	0.505	0.535	0.615	0.550	0.630
15	0.800	0.775	0.635	0.690	0.605	0.510	0.575	0.510	0.550	0.625	0.560	0.635
16	0.820	0.764	0.635	0.705	0.605	0.525	0.575	0.525	0.585	0.650	0.600	0.660
17	0.900	0.815	0.640	0.705	0.610	0.535	0.565	0.565	0.605	0.675	0.645	0.700
18	0.900	0.857	0.645	0.690	0.635	0.550	0.540	0.580	0.610	0.685	0.695	0.710
19	0.890	0.802	0.630	0.675	0.625	0.555	0.540	0.580	0.600	0.700	0.695	0.695
20	0.875	0.777	0.620	0.675	0.600	0.540	0.530	0.555	0.590	0.680	0.650	0.675
21	0.835	0.756	0.635	0.650	0.585	0.515	0.525	0.530	0.565	0.625	0.595	0.660
22	0.737	0.737	0.645	0.595	0.575	0.480	0.508	0.515	0.540	0.575	0.575	0.620
23	0.713	0.702	0.645	0.550	0.520	0.465	0.495	0.485	0.495	0.505	0.500	0.570

*1.000 = 6100 megawatts

** Load for 1 hour period following time indicated; 0 hour is midnight.

WEEKDAY LOAD MODEL FOR A WINTER PEAKING UTILITY

Fraction of Annual Peak Load Energy by Hour*

Time Period**	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
0	0.664	0.664	0.656	0.492	0.459	0.451	0.418	0.426	0.426	0.434	0.451	0.533
1	0.639	0.639	0.623	0.459	0.451	0.443	0.377	0.402	0.410	0.426	0.434	0.525
2	0.615	0.610	0.598	0.443	0.443	0.443	0.369	0.393	0.402	0.410	0.410	0.516
3	0.607	0.602	0.582	0.451	0.443	0.451	0.361	0.377	0.393	0.426	0.410	0.525
4	0.615	0.607	0.590	0.459	0.467	0.475	0.369	0.393	0.410	0.459	0.426	0.533
5	0.664	0.658	0.607	0.492	0.475	0.492	0.377	0.451	0.451	0.557	0.451	0.557
6	0.779	0.750	0.631	0.582	0.484	0.516	0.443	0.492	0.492	0.721	0.484	0.566
7	0.902	0.875	0.648	0.705	0.508	0.516	0.574	0.516	0.508	0.787	0.508	0.574
8	0.984	0.970	0.672	0.795	0.533	0.525	0.648	0.533	0.533	0.795	0.525	0.574
9	0.984	0.980	0.680	0.803	0.574	0.525	0.689	0.541	0.541	0.779	0.525	0.598
10	0.975	0.965	0.664	0.795	0.590	0.516	0.697	0.566	0.557	0.762	0.557	0.639
11	0.967	0.950	0.648	0.787	0.615	0.516	0.697	0.541	0.549	0.730	0.574	0.639
12	0.918	0.900	0.639	0.754	0.607	0.541	0.680	0.541	0.508	0.730	0.549	0.615
13	0.918	0.900	0.631	0.762	0.639	0.549	0.689	0.615	0.532	0.705	0.557	0.623
14	0.902	0.890	0.623	0.738	0.664	0.566	0.672	0.639	0.574	0.697	0.598	0.664
15	0.902	0.890	0.664	0.730	0.705	0.582	0.664	0.680	0.631	0.713	0.631	0.713
16	0.967	0.925	0.705	0.730	0.697	0.607	0.656	0.680	0.672	0.738	0.656	0.746
17	1.000	1.000	0.762	0.738	0.689	0.607	0.664	0.664	0.656	0.770	0.738	0.738
18	0.992	0.935	0.746	0.762	0.680	0.590	0.631	0.672	0.664	0.770	0.713	0.730
19	0.975	0.960	0.730	0.779	0.680	0.590	0.607	0.664	0.643	0.738	0.713	0.730
20	0.934	0.940	0.721	0.762	0.639	0.566	0.607	0.639	0.639	0.689	0.680	0.689
21	0.877	0.876	0.705	0.705	0.623	0.557	0.631	0.607	0.623	0.607	0.648	0.656
22	0.811	0.800	0.689	0.631	0.590	0.533	0.574	0.566	0.574	0.541	0.590	0.623
23	0.738	0.710	0.680	0.557	0.525	0.508	0.492	0.516	0.500	0.484	0.525	0.582

*1.000 = 6100 megawatts

**Load for 1 hour period following time indicated; 0 hour is midnight.

BASELINE COSTS OF WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	6100.00	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5508.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5	JUN 8	6437	0.73	9503.	3186586.	40.119	0.	5.19	0.	45.313	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 3	DEC 7	6751	0.76	9602.	2667349.	33.933	0.	4.62	0.	38.556	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26	JUN 29	6750	0.76	9603.	2653900.	33.767	0.	4.61	0.	38.378	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.70	9309.	4897668.	103.189	0.	8.23	0.	111.418	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3	MAR 30	6112	0.67	9714.	1772276.	22.809	0.	4.08	0.	26.887	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 8	OCT 5	6021	0.67	10014.	1172124.	15.551	0.	3.06	0.	18.608	1.325
8	COAL6	200.0	200.0	0.070	3	JUL 28	AUG 24	5638	0.62	10018.	1087792.	14.438	0.	2.98	0.	17.418	1.325
3	COAL3	100.0	100.0	0.060	3	DEC 8	DEC 28	5288	0.58	12014.	506628.	8.064	0.	1.69	0.	9.752	1.325
4	COAL4	100.0	100.0	0.060	3	OCT 27	NOV 16	5026	0.54	12025.	474529.	7.560	0.	1.65	0.	9.215	1.325
2	COAL2	100.0	100.0	0.060	3	OCT 6	OCT 26	4697	0.50	12031.	438262.	6.986	0.	1.62	0.	8.602	1.325
1	COAL1	100.0	100.0	0.060	3	AUG 4	AUG 24	4513	0.48	12036.	418861.	6.679	0.	1.60	0.	8.275	1.325
16	OIL66	600.0	600.0	0.220	2	AUG 25	SEP 28	3877	0.33	9458.	1750224.	37.467	0.	3.93	0.	41.397	2.263
15	OIL65	500.0	499.9	0.190	2	AUG 4	SEP 7	2519	0.20	9596.	868416.	18.861	0.	3.31	0.	22.174	2.263
11	OIL64	300.0	300.0	0.100	2	DEC 1	DEC 28	1511	0.13	9836.	351299.	7.821	0.	2.76	0.	10.581	2.263
9	OIL63	200.0	199.9	0.070	2	APR 28	MAY 25	1024	0.10	10105.	171660.	3.926	0.	2.13	0.	6.056	2.263
5	OIL61	100.0	100.3	0.060	2	MAR 31	APR 20	785	0.08	12042.	68771.	1.874	0.	1.23	0.	3.105	2.263
6	OIL62	100.0	97.2	0.060	2	SEP 8	SEP 28	672	0.07	12042.	58511.	1.595	0.	1.22	0.	2.815	2.263
31	NAT13	100.0	85.0	0.150	1	JUN 9	JUL 6	570	0.05	12300.	44776.	2.189	0.	0.59	0.	2.782	3.975
32	NAT14	100.0	85.0	0.150	1	MAR 3	MAR 30	488	0.04	12286.	38737.	1.892	0.	0.59	0.	2.483	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 10	NOV 30	437	0.04	14025.	18623.	1.038	0.	0.30	0.	1.334	3.975
28	NAT10	50.0	43.0	0.140	1	AUG 4	AUG 24	410	0.04	14040.	17341.	0.968	0.	0.30	0.	1.263	3.975
29	NAT11	50.0	43.0	0.140	1	OCT 6	OCT 26	370	0.04	14034.	15588.	0.870	0.	0.29	0.	1.164	3.975
30	NAT12	50.0	43.0	0.140	1	DEC 8	DEC 28	329	0.03	14030.	13993.	0.780	0.	0.29	0.	1.074	3.975
25	NAT7	25.0	22.3	0.110	1	AUG 4	AUG 17	303	0.03	14521.	6671.	0.385	0.	0.15	0.	0.532	3.975
26	NAT8	25.0	22.3	0.110	1	MAR 31	APR 13	292	0.03	14518.	6422.	0.371	0.	0.15	0.	0.517	3.975
21	NAT3	25.0	22.3	0.110	1	APR 14	APR 27	277	0.03	14521.	6094.	0.352	0.	0.15	0.	0.498	3.975
22	NAT4	25.0	22.3	0.110	1	OCT 20	NOV 2	265	0.03	14511.	5850.	0.337	0.	0.15	0.	0.484	3.975
23	NAT5	25.0	22.3	0.110	1	NOV 17	NOV 30	259	0.03	14521.	5696.	0.329	0.	0.15	0.	0.475	3.975
24	NAT6	25.0	22.3	0.110	1	OCT 27	NOV 9	245	0.02	14517.	5431.	0.313	0.	0.15	0.	0.460	3.975
19	NAT1	25.0	22.3	0.110	1	APR 14	APR 27	235	0.02	14509.	5261.	0.303	0.	0.15	0.	0.450	3.975
20	NAT2	25.0	22.3	0.110	1	NOV 17	NOV 30	235	0.02	14518.	5189.	0.299	0.	0.15	0.	0.446	3.975
	TIEAID										89940.	0.540				0.540	6.000
	THERMAL TOTALS										27882180.	409.072	0.	63.84	0.	472.915	
	PRESENT VALUE OF TOTALS											385.917	0.	60.23	0.	446.147	

REFRIGERATOR COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE 0.06
OPERATION + MAINTENANCE INFLATION FACTOR 0.03
PEAK LOAD (MW) 6100.00
THERMAL PEAK (MW) 5202.00

SPINNING RESERVE REQUIREMENT 0.
NIGHTLY PEAK LOAD ADDER (MW) 0.
MAXIMUM CAPACITY (MW) 6400.00
CONTINUOUS CAPACITY (MW) 6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5	JUN 8	6437	0.73	9500.	3214458.	40.460	0.	5.22	0.	45.677	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 3	DEC 7	6751	0.77	9601.	2693596.	34.262	0.	4.64	0.	38.906	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26	JUN 29	6750	0.77	9600.	2688248.	34.193	0.	4.64	0.	38.832	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.71	9303.	5022010.	105.743	0.	8.32	0.	114.059	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3	MAR 30	6730	0.74	9716.	1950868.	25.112	0.	4.24	0.	29.356	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 8	OCT 5	6477	0.72	10011.	1261904.	16.737	0.	3.14	0.	19.878	1.325
8	COAL6	200.0	200.0	0.070	3	JUL 28	AUG 24	6102	0.66	10031.	1153331.	15.328	0.	3.04	0.	18.368	1.325
3	COAL3	100.0	100.0	0.060	3	DEC 8	DEC 28	5464	0.59	12014.	520440.	8.284	0.	1.70	0.	9.986	1.325
4	COAL4	100.0	100.0	0.060	3	OCT 27	NOV 16	5186	0.55	12036.	481706.	7.681	0.	1.66	0.	9.343	1.325
2	COAL2	100.0	100.0	0.060	3	OCT 6	OCT 26	4791	0.50	12036.	441512.	7.040	0.	1.62	0.	8.660	1.325
1	COAL1	100.0	100.0	0.060	3	AUG 4	AUG 24	4602	0.48	12046.	417448.	6.663	0.	1.59	0.	8.257	1.325
16	OIL66	600.0	600.0	0.220	2	AUG 25	SEP 28	4008	0.31	9485.	1628933.	34.971	0.	3.85	0.	38.817	2.263
15	OIL65	500.0	499.7	0.190	2	AUG 4	SEP 7	2280	0.17	9623.	738909.	16.094	0.	3.21	0.	19.302	2.263
11	OIL64	300.0	300.0	0.100	2	DEC 1	DEC 28	1188	0.10	9850.	267588.	5.966	0.	2.68	0.	8.648	2.263
9	OIL63	200.0	198.1	0.070	2	APR 28	MAY 25	753	0.07	10162.	118517.	2.726	0.	2.08	0.	4.807	2.263
5	OIL61	100.0	96.4	0.060	2	MAR 31	APR 20	521	0.05	12051.	45203.	1.233	0.	1.21	0.	2.439	2.263
6	OIL62	100.0	94.0	0.060	2	SEP 8	SEP 28	447	0.04	12080.	37265.	1.019	0.	1.20	0.	2.217	2.263
31	NAT13	100.0	85.0	0.150	1	JUN 9	JUL 6	357	0.03	12364.	27367.	1.345	0.	0.59	0.	1.933	3.975
32	NAT14	100.0	85.0	0.150	1	MAR 3	MAR 30	282	0.03	12321.	22083.	1.081	0.	0.59	0.	1.668	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 10	NOV 30	254	0.02	14018.	10791.	0.601	0.	0.29	0.	0.894	3.975
28	NAT10	50.0	43.0	0.140	1	AUG 4	AUG 24	243	0.02	14049.	10227.	0.571	0.	0.29	0.	0.864	3.975
29	NAT11	50.0	43.0	0.140	1	OCT 6	OCT 26	216	0.02	14039.	9150.	0.511	0.	0.29	0.	0.803	3.975
30	NAT12	50.0	43.0	0.140	1	DEC 8	DEC 28	197	0.02	14068.	8224.	0.460	0.	0.29	0.	0.752	3.975
25	NAT7	25.0	22.3	0.110	1	AUG 4	AUG 17	166	0.02	14518.	3673.	0.212	0.	0.15	0.	0.358	3.975
26	NAT8	25.0	22.3	0.110	1	MAR 31	APR 13	156	0.02	14531.	3437.	0.199	0.	0.15	0.	0.344	3.975
21	NAT3	25.0	22.3	0.110	1	APR 14	APR 27	147	0.01	14529.	3228.	0.186	0.	0.15	0.	0.332	3.975
22	NAT4	25.0	22.3	0.110	1	OCT 20	NOV 2	138	0.01	14533.	3039.	0.176	0.	0.15	0.	0.321	3.975
23	NAT5	25.0	22.3	0.110	1	NOV 17	NOV 30	125	0.01	14519.	2783.	0.161	0.	0.15	0.	0.306	3.975
24	NAT6	25.0	22.3	0.110	1	OCT 27	NOV 9	121	0.01	14531.	2663.	0.154	0.	0.15	0.	0.300	3.975
19	NAT1	25.0	22.3	0.110	1	APR 14	APR 27	114	0.01	14514.	2506.	0.145	0.	0.15	0.	0.290	3.975
20	NAT2	25.0	22.3	0.110	1	NOV 17	NOV 30	110	0.01	14512.	2471.	0.143	0.	0.15	0.	0.288	3.975
	TIEAID										38527.	0.231				0.231	6.000
THERMAL TOTALS											27883818.	403.155	0.	63.95	0.	467.101	
PRESENT VALUE OF TOTALS												380.335	0.	60.33	0.	440.662	

ANNUAL LOAD ENERGY (MWHRS) 33,152,593,000

Arthur D Little, Inc.

4-HOUR WATER HEATING COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	6100.00	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5508.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.362	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5	JUN 3	6437	0.73	9500.	3209053.	40.392	0.	5.21	0.	45.605	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 3	DEC 7	6751	0.76	9599.	2680539.	34.092	0.	4.63	0.	38.725	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26	JUN 29	6750	0.76	9599.	2668569.	33.939	0.	4.62	0.	38.562	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.71	9304.	4977482.	104.821	0.	8.28	0.	113.105	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3	MAR 30	6448	0.71	9709.	1881812.	24.207	0.	4.18	0.	28.387	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 8	OCT 5	6319	0.70	10017.	1221191.	16.208	0.	3.10	0.	19.311	1.325
8	COAL6	200.0	200.0	0.070	3	JUL 28	AUG 24	5883	0.64	10028.	1120863.	14.892	0.	3.01	0.	17.903	1.325
3	COAL3	100.0	100.0	0.060	3	DEC 8	DEC 23	5270	0.57	12017.	502339.	7.998	0.	1.68	0.	9.682	1.325
4	COAL4	100.0	100.0	0.060	3	OCT 27	NOV 16	4995	0.54	12024.	471222.	7.507	0.	1.65	0.	9.158	1.325
2	COAL2	100.0	100.0	0.060	3	OCT 6	OCT 26	4677	0.49	12032.	434534.	6.928	0.	1.61	0.	8.540	1.325
1	COAL1	100.0	100.0	0.060	3	AUG 4	AUG 24	4528	0.47	12047.	411271.	6.564	0.	1.59	0.	8.152	1.325
16	OIL66	600.0	600.0	0.220	2	AUG 25	SEP 23	3318	0.32	9467.	1672898.	35.844	0.	3.88	0.	39.720	2.263
15	OIL65	500.0	500.0	0.190	2	AUG 4	SEP 7	2349	0.19	9538.	818835.	17.769	0.	3.27	0.	21.042	2.263
11	OIL64	300.0	300.0	0.100	2	DEC 1	DEC 23	1356	0.12	9845.	310624.	6.922	0.	2.72	0.	9.644	2.263
9	OIL63	200.0	200.0	0.070	2	APR 28	MAY 25	863	0.08	10108.	144918.	3.315	0.	2.11	0.	5.421	2.263
5	OIL61	100.0	100.3	0.060	2	MAR 31	APR 20	677	0.07	12067.	57782.	1.578	0.	1.22	0.	2.798	2.263
6	OIL62	100.0	97.0	0.060	2	SEP 8	SEP 23	564	0.05	12086.	46963.	1.285	0.	1.21	0.	2.493	2.263
31	NAT13	100.0	85.0	0.150	1	JUN 9	JUL 6	449	0.04	12251.	35949.	1.751	0.	0.59	0.	2.341	3.975
32	NAT14	100.0	85.0	0.150	1	MAR 3	MAR 30	396	0.04	12247.	31836.	1.550	0.	0.59	0.	2.139	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 10	NOV 30	363	0.03	14038.	15351.	0.857	0.	0.29	0.	1.151	3.975
28	NAT10	50.0	43.0	0.140	1	AUG 4	AUG 24	329	0.03	14045.	13874.	0.775	0.	0.29	0.	1.069	3.975
29	NAT11	50.0	43.0	0.140	1	OCT 6	OCT 26	284	0.03	14043.	11951.	0.667	0.	0.29	0.	0.960	3.975
30	NAT12	50.0	43.0	0.140	1	DEC 8	DEC 28	253	0.02	14047.	10600.	0.592	0.	0.29	0.	0.885	3.975
25	NAT7	25.0	22.2	0.110	1	AUG 4	AUG 17	226	0.02	14512.	4981.	0.287	0.	0.15	0.	0.434	3.975
26	NAT8	25.0	22.2	0.110	1	MAR 31	APR 13	220	0.02	14511.	4883.	0.282	0.	0.15	0.	0.428	3.975
21	NAT3	25.0	22.2	0.110	1	APR 14	APR 27	210	0.02	14518.	4602.	0.266	0.	0.15	0.	0.412	3.975
22	NAT4	25.0	22.2	0.110	1	OCT 20	NOV 2	200	0.02	14507.	4449.	0.257	0.	0.15	0.	0.403	3.975
23	NAT5	25.0	22.2	0.110	1	NOV 17	NOV 30	200	0.02	14515.	4420.	0.255	0.	0.15	0.	0.401	3.975
24	NAT6	25.0	22.2	0.110	1	OCT 27	NOV 9	194	0.02	14510.	4277.	0.247	0.	0.15	0.	0.393	3.975
19	NAT1	25.0	22.2	0.110	1	APR 14	APR 27	191	0.02	14510.	4193.	0.242	0.	0.15	0.	0.388	3.975
20	NAT2	25.0	22.2	0.110	1	NOV 17	NOV 30	188	0.02	14516.	4130.	0.238	0.	0.15	0.	0.384	3.975
	TIEAID										66845.	0.401				0.401	6.000
	THERMAL TOTALS										27905058.	406.392	0.	63.91	0.	470.298	
	PRESENT VALUE OF TOTALS											383.389	0.	60.29	0.	443.677	

ANNUAL LOAD ENERGY (MWHRS) 33175458.

Arthur D Little, Inc.

8-HOUR WATER HEATING COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	6002.40	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5418.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	AUG 11	SEP 28	6319	0.72	10001.	5051687.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	NOV 3	DEC 7	6437	0.73	9500.	3209544.	40.399	0.	5.21	0.	45.612	1.325
12	COAL8	400.0	400.0	0.150	168	JUL 7	AUG 10	6750	0.76	9599.	2682537.	34.117	0.	4.63	0.	38.751	1.325
13	COAL9	400.0	400.0	0.150	168	NOV 24	DEC 28	6750	0.76	9600.	2671743.	33.980	0.	4.63	0.	38.606	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.71	9304.	5004722.	105.388	0.	8.30	0.	113.692	2.263
10	COAL7	300.0	300.0	0.100	3	JUN 9	JUL 6	6829	0.76	9709.	2001459.	25.745	0.	4.29	0.	30.036	1.325
7	COAL5	200.0	200.0	0.070	3	JUL 21	AUG 17	6425	0.71	10015.	1244562.	16.515	0.	3.12	0.	19.640	1.325
8	COAL6	200.0	200.0	0.070	3	MAR 3	MAR 30	5833	0.63	10023.	1115419.	14.812	0.	3.01	0.	17.317	1.325
3	COAL3	100.0	100.0	0.060	3	SEP 1	SEP 21	5400	0.58	12024.	508546.	8.102	0.	1.69	0.	9.792	1.325
4	COAL4	100.0	100.0	0.060	3	JUN 9	JUN 29	5101	0.54	12026.	475028.	7.569	0.	1.65	0.	9.224	1.325
2	COAL2	100.0	100.0	0.060	3	DEC 8	DEC 28	4610	0.48	12040.	422987.	6.747	0.	1.60	0.	8.348	1.325
1	COAL1	100.0	100.0	0.060	3	JUN 9	JUN 29	4431	0.46	12044.	403324.	6.436	0.	1.58	0.	8.016	1.325
16	OIL66	600.0	600.0	0.220	2	JUN 16	JUL 20	3731	0.30	9475.	1579010.	33.863	0.	3.81	0.	37.674	2.263
15	OIL65	500.0	499.8	0.190	2	MAY 5	JUN 8	2329	0.18	9595.	802187.	17.421	0.	3.26	0.	20.680	2.263
11	OIL64	300.0	300.0	0.100	2	OCT 27	NOV 23	1300	0.11	9850.	294392.	6.563	0.	2.71	0.	9.270	2.263
9	OIL63	200.0	199.9	0.070	2	MAY 5	JUN 1	810	0.07	10134.	131247.	3.011	0.	2.09	0.	5.103	2.263
5	OIL61	100.0	100.6	0.060	2	JUL 21	AUG 10	599	0.06	12062.	51142.	1.396	0.	1.21	0.	2.609	2.263
6	OIL62	100.0	97.2	0.060	2	SEP 22	OCT 12	503	0.05	12078.	42030.	1.150	0.	1.20	0.	2.354	2.263
31	NAT13	100.0	85.0	0.150	1	SEP 1	SEP 28	397	0.04	12306.	31379.	1.535	0.	0.59	0.	2.124	3.975
32	NAT14	100.0	85.0	0.150	1	MAR 3	MAR 30	347	0.03	12311.	27188.	1.330	0.	0.59	0.	1.918	3.975
27	NAT9	50.0	43.0	0.140	1	DEC 8	DEC 23	302	0.03	14029.	12840.	0.716	0.	0.29	0.	1.010	3.975
28	NAT10	50.0	43.0	0.140	1	OCT 6	OCT 26	284	0.03	14035.	12037.	0.671	0.	0.29	0.	0.965	3.975
29	NAT11	50.0	43.0	0.140	1	DEC 8	DEC 28	256	0.02	14059.	10732.	0.600	0.	0.29	0.	0.893	3.975
30	NAT12	50.0	43.0	0.140	1	JUN 9	JUN 29	217	0.02	14056.	9082.	0.507	0.	0.29	0.	0.800	3.975
25	NAT7	25.0	22.2	0.110	1	APR 14	APR 27	188	0.02	14524.	4120.	0.238	0.	0.15	0.	0.384	3.975
26	NAT8	25.0	22.2	0.110	1	NOV 3	NOV 16	181	0.02	14517.	3931.	0.227	0.	0.15	0.	0.373	3.975
21	NAT3	25.0	22.2	0.110	1	AUG 18	AUG 31	174	0.02	14510.	3326.	0.221	0.	0.15	0.	0.367	3.975
22	NAT4	25.0	22.2	0.110	1	JUL 28	AUG 10	169	0.02	14510.	3756.	0.217	0.	0.15	0.	0.363	3.975
23	NAT5	25.0	22.2	0.110	1	JUN 16	JUN 29	163	0.02	14524.	3615.	0.209	0.	0.15	0.	0.355	3.975
24	NAT6	25.0	22.2	0.110	1	MAR 31	APR 13	156	0.02	14516.	3429.	0.198	0.	0.15	0.	0.344	3.975
19	NAT1	25.0	22.2	0.110	1	JUL 28	AUG 10	150	0.02	14512.	3342.	0.193	0.	0.15	0.	0.339	3.975
20	NAT2	25.0	22.2	0.110	1	JUN 16	JUN 29	146	0.01	14518.	3257.	0.188	0.	0.15	0.	0.334	3.975
	TIEAID										52577.	0.315				0.315	6.000
	THERMAL TOTALS										27876726.	404.045	0.	63.92	0.	467.966	
	PRESENT VALUE OF TOTALS											381.174	0.	60.30	0.	441.477	

ANNUAL LOAD ENERGY (MWHRS) 33147126.

Arthur D Little, Inc.

16-HOUR WATER HEATING COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	5807.20	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5202.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10002.	5046121.	33.434	0.	6.39	0.	39.826	0.662
14	COAL10	500.0	500.0	0.190	168	SEP 8	OCT 12	6436	0.73	9502.	3190159.	40.162	0.	5.20	0.	45.359	1.325
12	COAL8	400.0	400.0	0.150	168	OCT 27	NOV 30	6750	0.76	9604.	2653543.	33.763	0.	4.61	0.	38.374	1.325
13	COAL9	400.0	400.0	0.150	168	NOV 24	DEC 28	6750	0.75	9605.	2641179.	33.610	0.	4.60	0.	38.211	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.70	9306.	4944671.	104.151	0.	8.26	0.	112.413	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 31	APR 27	6712	0.74	9715.	1954854.	25.161	0.	4.25	0.	29.408	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 1	SEP 28	6398	0.70	10019.	1234002.	16.381	0.	3.12	0.	19.496	1.325
8	COAL6	200.0	200.0	0.070	3	JUN 2	JUN 29	5809	0.63	10033.	1098328.	14.599	0.	2.99	0.	17.589	1.325
3	COAL3	100.0	100.0	0.060	3	OCT 6	OCT 26	5306	0.57	12030.	497467.	7.929	0.	1.68	0.	9.607	1.325
4	COAL4	100.0	100.0	0.060	3	APR 7	APR 27	4969	0.52	12045.	456859.	7.291	0.	1.64	0.	8.927	1.325
2	COAL2	100.0	100.0	0.060	3	NOV 3	NOV 23	4819	0.51	12039.	446515.	7.122	0.	1.63	0.	8.747	1.325
1	COAL1	100.0	100.0	0.060	3	MAY 5	MAY 25	4597	0.48	12051.	419147.	6.692	0.	1.60	0.	8.289	1.325
16	OIL66	600.0	599.8	0.220	2	AUG 4	SEP 7	3835	0.33	9453.	1757762.	37.609	0.	3.94	0.	41.544	2.263
15	OIL65	500.0	499.8	0.190	2	APR 28	JUN 1	2467	0.19	9590.	846339.	18.372	0.	3.30	0.	21.667	2.263
11	OIL64	300.0	300.0	0.100	2	OCT 13	NOV 9	1357	0.12	9852.	305262.	6.807	0.	2.72	0.	9.524	2.263
9	OIL63	200.0	191.6	0.070	2	AUG 4	AUG 31	855	0.07	10199.	130100.	3.003	0.	2.09	0.	5.095	2.263
5	OIL61	100.0	94.0	0.060	2	MAY 12	JUN 1	563	0.06	12051.	49161.	1.341	0.	1.21	0.	2.552	2.263
6	OIL62	100.0	94.0	0.060	2	DEC 1	DEC 21	499	0.05	12104.	40729.	1.116	0.	1.20	0.	2.318	2.263
31	NAT13	100.0	85.0	0.150	1	MAR 3	MAR 30	371	0.03	12433.	27967.	1.382	0.	0.59	0.	1.970	3.975
32	NAT14	100.0	85.0	0.150	1	SEP 8	OCT 5	303	0.03	12304.	23725.	1.160	0.	0.59	0.	1.747	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 3	NOV 23	255	0.02	14023.	10816.	0.603	0.	0.29	0.	0.896	3.975
28	NAT10	50.0	43.0	0.140	1	MAY 26	JUN 15	243	0.02	14040.	10212.	0.570	0.	0.29	0.	0.863	3.975
29	NAT11	50.0	43.0	0.140	1	OCT 6	OCT 26	213	0.02	14039.	9006.	0.503	0.	0.29	0.	0.795	3.975
30	NAT12	50.0	43.0	0.140	1	APR 7	APR 27	194	0.02	14046.	8145.	0.455	0.	0.29	0.	0.747	3.975
25	NAT7	25.0	22.2	0.110	1	JUN 16	JUN 29	172	0.02	14542.	3740.	0.216	0.	0.15	0.	0.362	3.975
26	NAT8	25.0	22.2	0.110	1	AUG 4	AUG 17	153	0.02	14537.	3323.	0.192	0.	0.15	0.	0.338	3.975
21	NAT3	25.0	22.2	0.110	1	NOV 10	NOV 23	142	0.01	14549.	3056.	0.177	0.	0.15	0.	0.323	3.975
22	NAT4	25.0	22.2	0.110	1	OCT 13	OCT 26	125	0.01	14510.	2739.	0.158	0.	0.15	0.	0.304	3.975
23	NAT5	25.0	22.2	0.110	1	MAY 5	MAY 18	122	0.01	14515.	2703.	0.156	0.	0.15	0.	0.302	3.975
24	NAT6	25.0	22.2	0.110	1	DEC 15	DEC 28	120	0.01	14526.	2611.	0.151	0.	0.15	0.	0.296	3.975
19	NAT1	25.0	22.2	0.110	1	NOV 10	NOV 23	114	0.01	14522.	2478.	0.143	0.	0.15	0.	0.289	3.975
20	NAT2	25.0	22.2	0.110	1	NOV 10	NOV 23	106	0.01	14524.	2304.	0.136	0.	0.15	0.	0.282	3.975
	TIEAID										34003.	0.204				0.204	6.000
THERMAL TOTALS											27859140.	404.748	0.	63.91	0.	468.663	
PRESENT VALUE OF TOTALS												381.838	0.	60.30	0.	442.135	

ANNUAL LOAD ENERGY (MWHRS) 33129540.

Arthur D Little, Inc

SPACE HEATING COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE 0.06
OPERATION + MAINTENANCE INFLATION FACTOR 0.03
PEAK LOAD (MW) 5819.40
THERMAL PEAK (MW) 5220.00

SPINNING RESERVE REQUIREMENT 0.
NIGHTLY PEAK LOAD ADDER (MW) 0.
MAXIMUM CAPACITY (MW) 6400.00
CONTINUOUS CAPACITY (MW) 6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	300.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	NOV 3	DEC 7	6437	0.73	9502.	3192604.	40.190	0.	5.20	0.	45.389	1.325
12	COAL8	400.0	400.0	0.150	168	AUG 4	SEP 7	6750	0.76	9600.	2677208.	34.052	0.	4.63	0.	38.683	1.325
13	COAL9	400.0	400.0	0.150	168	NOV 24	DEC 28	6750	0.76	9601.	2659939.	33.835	0.	4.62	0.	38.451	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.70	9307.	4921128.	103.666	0.	8.25	0.	111.911	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3	MAR 30	6265	0.69	9712.	1826645.	23.504	0.	4.13	0.	27.633	1.325
7	COAL5	200.0	200.0	0.070	3	JUL 28	AUG 24	6120	0.68	10013.	1192885.	15.825	0.	3.08	0.	18.902	1.325
8	COAL6	200.0	200.0	0.070	3	SEP 8	OCT 5	5886	0.65	10018.	1138386.	15.110	0.	3.03	0.	18.136	1.325
3	COAL3	100.0	100.0	0.060	3	AUG 4	AUG 24	5428	0.59	12015.	519522.	8.270	0.	1.70	0.	9.971	1.325
4	COAL4	100.0	100.0	0.060	3	DEC 8	DEC 28	5005	0.54	12022.	473912.	7.548	0.	1.65	0.	9.202	1.325
2	COAL2	100.0	100.0	0.060	3	NOV 3	NOV 23	4878	0.52	12030.	456678.	7.279	0.	1.64	0.	8.914	1.325
1	COAL1	100.0	100.0	0.060	3	DEC 8	DEC 28	4430	0.47	12031.	410757.	6.547	0.	1.59	0.	8.135	1.325
16	OIL66	600.0	599.9	0.220	2	AUG 25	SEP 28	3965	0.33	9464.	1751761.	37.525	0.	3.93	0.	41.456	2.263
15	OIL65	500.0	499.9	0.190	2	MAY 5	JUN 8	2567	0.20	9606.	863698.	18.779	0.	3.31	0.	22.088	2.263
11	OIL64	300.0	299.9	0.100	2	JUN 2	JUN 29	1419	0.12	9828.	327549.	7.286	0.	2.74	0.	10.024	2.263
9	OIL63	200.0	194.5	0.070	2	MAR 3	MAR 30	900	0.08	10177.	139448.	3.212	0.	2.10	0.	5.312	2.263
5	OIL61	100.0	94.0	0.060	2	MAY 5	MAY 25	620	0.06	12071.	52816.	1.443	0.	1.21	0.	2.657	2.263
6	OIL62	100.0	94.0	0.060	2	JUN 9	JUN 29	531	0.05	12064.	45636.	1.246	0.	1.21	0.	2.453	2.263
31	NAT13	100.0	85.0	0.150	1	OCT 27	NOV 23	442	0.04	12525.	32247.	1.605	0.	0.59	0.	2.195	3.975
32	NAT14	100.0	85.0	0.150	1	MAR 31	APR 27	327	0.03	12311.	25628.	1.254	0.	0.59	0.	1.841	3.975
27	NAT9	50.0	43.0	0.140	1	AUG 4	AUG 24	287	0.03	14039.	12125.	0.677	0.	0.29	0.	0.970	3.975
28	NAT10	50.0	43.0	0.140	1	OCT 6	OCT 26	265	0.03	14026.	11201.	0.624	0.	0.29	0.	0.918	3.975
29	NAT11	50.0	43.0	0.140	1	DEC 8	DEC 28	247	0.02	14028.	10503.	0.586	0.	0.29	0.	0.879	3.975
30	NAT12	50.0	43.0	0.140	1	MAY 12	JUN 1	234	0.02	14042.	9878.	0.551	0.	0.29	0.	0.844	3.975
25	NAT7	25.0	22.2	0.110	1	APR 28	MAY 11	208	0.02	14538.	4562.	0.264	0.	0.15	0.	0.410	3.975
26	NAT8	25.0	22.2	0.110	1	AUG 11	AUG 24	188	0.02	14549.	4057.	0.235	0.	0.15	0.	0.381	3.975
21	NAT3	25.0	22.2	0.110	1	SEP 8	SEP 21	166	0.02	14533.	3635.	0.210	0.	0.15	0.	0.356	3.975
22	NAT4	25.0	22.2	0.110	1	OCT 6	OCT 19	153	0.02	14544.	3361.	0.194	0.	0.15	0.	0.340	3.975
23	NAT5	25.0	22.2	0.110	1	MAY 19	JUN 1	135	0.01	14517.	3029.	0.175	0.	0.15	0.	0.321	3.975
24	NAT6	25.0	22.2	0.110	1	JUN 9	JUN 22	133	0.01	14525.	2927.	0.169	0.	0.15	0.	0.315	3.975
19	NAT1	25.0	22.2	0.110	1	APR 28	MAY 11	124	0.01	14515.	2759.	0.159	0.	0.15	0.	0.305	3.975
20	NAT2	25.0	22.2	0.110	1	AUG 4	AUG 17	122	0.01	14514.	2696.	0.156	0.	0.15	0.	0.301	3.975
	TIEAID										42861.	0.257				0.257	6.000
	THERMAL TOTALS										27873756.	405.902	0.	63.91	0.	469.814	
	PRESENT VALUE OF TOTALS											382.926	0.	60.29	0.	443.221	

ANNUAL LOAD ENERGY (MWHRS) 33144156.

Arthur D Little, Inc.

LIGHTING COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE 0.06
OPERATION + MAINTENANCE INFLATION FACTOR 0.03
PEAK LOAD (MW) 6087.80
THERMAL PEAK (MW) 5490.00

SPINNING RESERVE REQUIREMENT 0.
NIGHTLY PEAK LOAD ADDER (MW) 0.
MAXIMUM CAPACITY (MW) 6400.00
CONTINUOUS CAPACITY (MW) 6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5	JUN 8	6437	0.73	9501.	3192974.	40.194	0.	5.20	0.	45.394	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 3	DEC 7	6751	0.76	9600.	2674735.	34.019	0.	4.63	0.	38.648	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26	JUN 29	6750	0.76	9601.	2661545.	33.856	0.	4.62	0.	38.473	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.70	9307.	4922674.	103.692	0.	8.25	0.	111.939	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3	MAR 30	6444	0.71	9717.	1858634.	23.929	0.	4.16	0.	28.087	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 8	OCT 5	6300	0.69	10019.	1218082.	16.169	0.	3.10	0.	19.269	1.325
8	COAL6	200.0	200.0	0.070	3	JUL 28	AUG 24	5859	0.63	10030.	1114396.	14.809	0.	3.00	0.	17.813	1.325
3	COAL3	100.0	100.0	0.060	3	DEC 8	DEC 23	5378	0.57	12033.	504988.	8.051	0.	1.69	0.	9.737	1.325
4	COAL4	100.0	100.0	0.060	3	OCT 27	NOV 16	5124	0.54	12042.	475956.	7.594	0.	1.66	0.	9.250	1.325
2	COAL2	100.0	100.0	0.060	3	OCT 6	OCT 26	4798	0.51	12037.	444301.	7.086	0.	1.62	0.	8.709	1.325
1	COAL1	100.0	100.0	0.060	3	AUG 4	AUG 24	4574	0.48	12040.	422417.	6.738	0.	1.60	0.	8.338	1.325
16	OIL66	600.0	600.0	0.220	2	AUG 25	SEP 28	3873	0.33	9456.	1730842.	37.043	0.	3.92	0.	40.959	2.263
15	OIL65	500.0	500.0	0.190	2	AUG 4	SEP 7	2423	0.19	9598.	817157.	17.751	0.	3.27	0.	21.023	2.263
11	OIL64	300.0	300.0	0.100	2	DEC 1	DEC 28	1387	0.12	9868.	311357.	6.954	0.	2.72	0.	9.678	2.263
9	OIL63	200.0	200.0	0.070	2	APR 28	MAY 25	889	0.08	10109.	147716.	3.380	0.	2.11	0.	5.487	2.263
5	OIL61	100.0	100.5	0.060	2	MAR 31	APR 20	652	0.06	12050.	56703.	1.546	0.	1.22	0.	2.765	2.263
6	OIL62	100.0	97.0	0.060	2	SEP 8	SEP 28	552	0.05	12044.	47967.	1.308	0.	1.21	0.	2.517	2.263
31	NAT13	100.0	85.0	0.150	1	MAR 3	MAR 30	456	0.04	12274.	36200.	1.766	0.	0.59	0.	2.357	3.975
32	NAT14	100.0	85.0	0.150	1	NOV 3	NOV 30	410	0.04	12345.	31920.	1.566	0.	0.59	0.	2.156	3.975
27	NAT9	50.0	43.0	0.140	1	JUN 9	JUN 29	356	0.03	14032.	15097.	0.842	0.	0.29	0.	1.136	3.975
23	NAT10	50.0	43.0	0.140	1	AUG 4	AUG 24	326	0.03	14045.	13710.	0.765	0.	0.29	0.	1.059	3.975
29	NAT11	50.0	43.0	0.140	1	OCT 6	OCT 26	291	0.03	14031.	12244.	0.683	0.	0.29	0.	0.976	3.975
30	NAT12	50.0	43.0	0.140	1	DEC 8	DEC 28	260	0.03	14030.	11016.	0.614	0.	0.29	0.	0.907	3.975
25	NAT7	25.0	22.2	0.110	1	JUN 9	JUN 22	240	0.02	14510.	5330.	0.307	0.	0.15	0.	0.454	3.975
26	NAT8	25.0	22.2	0.110	1	AUG 4	AUG 17	231	0.02	14519.	5108.	0.295	0.	0.15	0.	0.441	3.975
21	NAT3	25.0	22.2	0.110	1	JUN 16	JUN 29	217	0.02	14515.	4802.	0.277	0.	0.15	0.	0.423	3.975
22	NAT4	25.0	22.2	0.110	1	APR 14	APR 27	210	0.02	14511.	4635.	0.267	0.	0.15	0.	0.414	3.975
23	NAT5	25.0	22.2	0.110	1	OCT 20	NOV 2	205	0.02	14521.	4525.	0.261	0.	0.15	0.	0.407	3.975
24	NAT6	25.0	22.2	0.110	1	NOV 17	NOV 30	195	0.02	14524.	4325.	0.250	0.	0.15	0.	0.396	3.975
19	NAT1	25.0	22.2	0.110	1	APR 14	APR 27	185	0.02	14508.	4087.	0.236	0.	0.15	0.	0.382	3.975
20	NAT2	25.0	22.2	0.110	1	JUN 9	JUN 22	184	0.02	14513.	4053.	0.234	0.	0.15	0.	0.380	3.975
	TIEAID										68692.	0.412				0.412	6.000
	THERMAL TOTALS										27879948.	406.363	0.	63.89	0.	470.248	
	PRESENT VALUE OF TOTALS											383.361	0.	60.27	0.	443.630	

Arthur D Little, Inc.

TELEVISION COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	5971.90	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5382.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5	JUN 8	6437	0.73	9500.	3209901.	40.403	0.	5.21	0.	45.617	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 3	DEC 7	6751	0.76	9599.	2636098.	34.162	0.	4.64	0.	38.799	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26	JUN 29	6750	0.76	9600.	2675932.	34.034	0.	4.63	0.	38.663	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.71	9304.	4985088.	104.977	0.	8.29	0.	113.267	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3	MAR 30	6427	0.71	9710.	1874126.	24.111	0.	4.17	0.	28.283	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 8	OCT 5	6280	0.69	10017.	1214542.	16.118	0.	3.10	0.	19.215	1.325
8	COAL6	200.0	200.0	0.070	3	JUL 28	AUG 24	5868	0.64	10025.	1120320.	14.880	0.	3.01	0.	17.890	1.325
3	COAL3	100.0	100.0	0.060	3	OCT 6	OCT 26	5362	0.58	12022.	508766.	8.104	0.	1.69	0.	9.794	1.325
4	COAL4	100.0	100.0	0.060	3	DEC 8	DEC 28	5038	0.54	12026.	475539.	7.577	0.	1.66	0.	9.232	1.325
2	COAL2	100.0	100.0	0.060	3	NOV 3	NOV 23	4727	0.50	12039.	435053.	6.939	0.	1.61	0.	8.552	1.325
1	COAL1	100.0	100.0	0.060	3	AUG 4	AUG 24	4507	0.47	12045.	409231.	6.531	0.	1.59	0.	8.117	1.325
16	OIL66	600.0	599.9	0.220	2	AUG 25	SEP 28	3924	0.31	9480.	1636772.	35.120	0.	3.85	0.	38.971	2.263
15	OIL65	500.0	499.9	0.190	2	AUG 4	SEP 7	2306	0.18	9605.	778474.	16.924	0.	3.24	0.	20.164	2.263
11	OIL64	300.0	296.7	0.100	2	DEC 1	DEC 23	1311	0.11	9348.	299394.	6.673	0.	2.71	0.	9.386	2.263
9	OIL63	200.0	199.6	0.070	2	APR 28	MAY 25	854	0.08	10092.	142717.	3.260	0.	2.10	0.	5.363	2.263
5	OIL61	100.0	94.0	0.060	2	SEP 8	SEP 28	624	0.06	12075.	52649.	1.439	0.	1.21	0.	2.653	2.263
6	OIL62	100.0	94.0	0.060	2	MAR 3	MAR 23	522	0.05	12071.	44535.	1.217	0.	1.21	0.	2.422	2.263
31	NAT13	100.0	85.0	0.150	1	NOV 3	NOV 30	451	0.04	12297.	35649.	1.742	0.	0.59	0.	2.333	3.975
32	NAT14	100.0	85.0	0.150	1	OCT 6	NOV 2	394	0.03	12417.	29953.	1.478	0.	0.59	0.	2.067	3.975
27	NAT9	50.0	43.0	0.140	1	JUN 9	JUN 29	323	0.03	14036.	13637.	0.761	0.	0.29	0.	1.055	3.975
28	NAT10	50.0	43.0	0.140	1	AUG 4	AUG 24	294	0.03	14039.	12410.	0.692	0.	0.29	0.	0.986	3.975
29	NAT11	50.0	43.0	0.140	1	JUN 9	JUN 29	271	0.03	14046.	11415.	0.637	0.	0.29	0.	0.931	3.975
30	NAT12	50.0	43.0	0.140	1	MAR 10	MAR 30	239	0.02	14026.	10192.	0.568	0.	0.29	0.	0.861	3.975
25	NAT7	25.0	22.2	0.110	1	JUN 9	JUN 22	229	0.02	14519.	5062.	0.292	0.	0.15	0.	0.439	3.975
26	NAT8	25.0	22.2	0.110	1	NOV 17	NOV 30	217	0.02	14518.	4792.	0.277	0.	0.15	0.	0.423	3.975
21	NAT3	25.0	22.2	0.110	1	AUG 4	AUG 17	210	0.02	14511.	4616.	0.266	0.	0.15	0.	0.413	3.975
22	NAT4	25.0	22.2	0.110	1	SEP 8	SEP 21	205	0.02	14515.	4534.	0.262	0.	0.15	0.	0.408	3.975
23	NAT5	25.0	22.2	0.110	1	MAR 17	MAR 30	195	0.02	14536.	4267.	0.246	0.	0.15	0.	0.393	3.975
24	NAT6	25.0	22.2	0.110	1	MAY 5	MAY 18	179	0.02	14523.	3967.	0.229	0.	0.15	0.	0.375	3.975
19	NAT1	25.0	22.2	0.110	1	DEC 8	DEC 21	170	0.02	14515.	3756.	0.217	0.	0.15	0.	0.363	3.975
20	NAT2	25.0	22.2	0.110	1	DEC 15	DEC 28	167	0.02	14513.	3661.	0.211	0.	0.15	0.	0.357	3.975
	TIEAID										59081.	0.354				0.354	6.000
THERMAL TOTALS											27807840.	404.170	0.	63.84	0.	468.007	
PRESENT VALUE OF TOTALS												331.292	0.	60.22	0.	441.516	

Arthur D Little Inc.

RANGES AND OVENS COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	6002.40	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5418.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM - THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	AUG 11 SEP 28	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5 JUN 8	6437	0.73	9501.	3209262.	40.396	0.	5.21	0.	45.609	1.325
12	COAL8	400.0	400.0	0.150	168	JUL 7 AUG 10	6750	0.76	9600.	2682178.	34.114	0.	4.63	0.	38.748	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26 JUN 29	6750	0.76	9600.	2672851.	33.996	0.	4.63	0.	38.622	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2 JUN 15	6505	0.70	9306.	4939304.	104.049	0.	8.26	0.	112.307	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3 MAR 30	6639	0.73	9714.	1930069.	24.839	0.	4.22	0.	29.064	1.325
7	COAL5	200.0	200.0	0.070	3	JUL 21 AUG 17	6259	0.69	10015.	1209400.	16.047	0.	3.09	0.	19.140	1.325
8	COAL6	200.0	200.0	0.070	3	JUN 9 JUL 6	5950	0.64	10029.	1128468.	14.994	0.	3.02	0.	18.012	1.325
3	COAL3	100.0	100.0	0.060	3	MAR 3 MAR 23	5292	0.56	12038.	493047.	7.863	0.	1.67	0.	9.537	1.325
4	COAL4	100.0	100.0	0.060	3	SEP 1 SEP 21	5056	0.53	12054.	462599.	7.388	0.	1.64	0.	9.030	1.325
2	COAL2	100.0	104.1	0.060	3	JUL 21 AUG 10	4753	0.50	12039.	437712.	6.982	0.	1.62	0.	8.598	1.325
1	COAL1	100.0	106.6	0.060	3	DEC 8 DEC 28	4523	0.47	12033.	416939.	6.647	0.	1.59	0.	8.241	1.325
16	OIL66	600.0	600.0	0.220	2	JUN 16 JUL 20	3788	0.31	9473.	1629347.	34.934	0.	3.85	0.	38.780	2.263
15	OIL65	500.0	499.9	0.190	2	NOV 3 DEC 7	2398	0.19	9596.	819016.	17.788	0.	3.27	0.	21.061	2.263
11	OIL64	300.0	300.0	0.100	2	DEC 1 DEC 28	1351	0.12	9842.	310825.	6.924	0.	2.72	0.	9.646	2.263
9	OIL63	200.0	200.0	0.070	2	APR 28 MAY 25	894	0.08	10103.	149157.	3.411	0.	2.11	0.	5.520	2.263
5	OIL61	100.0	100.7	0.060	2	SEP 22 OCT 12	680	0.07	12073.	57605.	1.574	0.	1.22	0.	2.794	2.263
6	OIL62	100.0	97.2	0.060	2	NOV 3 NOV 23	557	0.05	12055.	48201.	1.315	0.	1.21	0.	2.525	2.263
31	NAT13	100.0	85.0	0.150	1	MAR 24 APR 20	464	0.04	12302.	36740.	1.796	0.	0.59	0.	2.387	3.975
32	NAT14	100.0	85.0	0.150	1	OCT 13 NOV 9	412	0.04	12270.	32843.	1.602	0.	0.59	0.	2.191	3.975
27	NAT9	50.0	43.0	0.140	1	DEC 8 DEC 28	370	0.04	14037.	15516.	0.866	0.	0.29	0.	1.160	3.975
28	NAT10	50.0	43.0	0.140	1	JUL 21 AUG 10	337	0.03	14033.	14326.	0.799	0.	0.29	0.	1.093	3.975
29	NAT11	50.0	43.0	0.140	1	MAR 3 MAR 23	306	0.03	14050.	12795.	0.715	0.	0.29	0.	1.008	3.975
30	NAT12	50.0	43.0	0.140	1	DEC 8 DEC 28	258	0.02	14041.	10907.	0.609	0.	0.29	0.	0.902	3.975
25	NAT7	25.0	22.2	0.110	1	SEP 15 SEP 28	235	0.02	14516.	5242.	0.302	0.	0.15	0.	0.449	3.975
26	NAT8	25.0	22.2	0.110	1	AUG 18 AUG 31	230	0.02	14521.	5071.	0.293	0.	0.15	0.	0.439	3.975
21	NAT3	25.0	22.2	0.110	1	AUG 18 AUG 31	219	0.02	14509.	4831.	0.281	0.	0.15	0.	0.428	3.975
22	NAT4	25.0	22.2	0.110	1	NOV 17 NOV 30	216	0.02	14514.	4797.	0.277	0.	0.15	0.	0.423	3.975
23	NAT5	25.0	22.2	0.110	1	JUN 16 JUN 29	209	0.02	14520.	4639.	0.268	0.	0.15	0.	0.414	3.975
24	NAT6	25.0	22.2	0.110	1	SEP 1 SEP 14	202	0.02	14514.	4458.	0.257	0.	0.15	0.	0.403	3.975
19	NAT1	25.0	22.2	0.110	1	JUN 16 JUN 29	197	0.02	14515.	4326.	0.250	0.	0.15	0.	0.396	3.975
20	NAT2	25.0	22.2	0.110	1	JUN 16 JUN 29	191	0.02	14515.	4200.	0.242	0.	0.15	0.	0.388	3.975
	TIEAID									70313.	0.422				0.422	6.000
	THERMAL TOTALS									27879246.	405.707	0.	63.89	0.	469.599	
	PRESENT VALUE OF TOTALS										382.743	0.	60.28	0.	443.018	

ANNUAL LOAD ENERGY (MWHRS) 33149646.

Arthur D Little, Inc.

AIR CONDITIONING COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	6100.00	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5508.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10001.	5051658.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5	JUN 3	6437	0.73	9501.	3202462.	40.312	0.	5.21	0.	45.519	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 3	DEC 7	6751	0.76	9601.	2677092.	34.052	0.	4.63	0.	38.682	1.325
13	COAL9	400.0	400.0	0.150	168	JUN 9	JUL 13	6750	0.76	9602.	2663913.	33.889	0.	4.62	0.	38.508	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.70	9307.	4926156.	103.773	0.	8.25	0.	112.022	2.263
10	COAL7	300.0	300.0	0.100	3	SEP 8	OCT 5	6461	0.71	9713.	1879892.	24.192	0.	4.18	0.	28.370	1.325
7	COAL5	200.0	200.0	0.070	3	DEC 1	DEC 28	6019	0.66	10017.	1165934.	15.473	0.	3.05	0.	18.526	1.325
3	COAL6	200.0	200.0	0.070	3	JUL 28	AUG 24	5817	0.63	10021.	1114821.	14.801	0.	3.00	0.	17.806	1.325
3	COAL3	100.0	100.0	0.060	3	SEP 8	SEP 23	5412	0.53	12021.	512260.	8.158	0.	1.69	0.	9.852	1.325
4	COAL4	100.0	100.0	0.060	3	AUG 4	AUG 24	5142	0.55	12029.	482044.	7.633	0.	1.66	0.	9.345	1.325
2	COAL2	100.0	100.0	0.060	3	JUN 9	JUN 29	4587	0.48	12040.	421273.	6.720	0.	1.60	0.	8.319	1.325
1	COAL1	100.0	112.5	0.060	3	DEC 8	DEC 28	4309	0.46	12031.	399761.	6.372	0.	1.58	0.	7.949	1.325
16	OIL66	600.0	600.0	0.220	2	AUG 25	SEP 28	3791	0.32	9465.	1670506.	35.788	0.	3.87	0.	39.662	2.263
15	OIL65	500.0	499.9	0.190	2	AUG 4	SEP 7	2346	0.18	9600.	801398.	17.413	0.	3.26	0.	20.672	2.263
11	OIL64	300.0	300.0	0.100	2	MAR 3	MAR 30	1369	0.12	9823.	323330.	7.188	0.	2.73	0.	9.923	2.263
9	OIL63	200.0	199.9	0.070	2	MAY 5	JUN 1	943	0.09	10098.	160148.	3.660	0.	2.12	0.	5.779	2.263
5	OIL61	100.0	100.3	0.060	2	JUL 7	JUL 27	755	0.08	12037.	66231.	1.804	0.	1.23	0.	3.033	2.263
6	OIL62	100.0	97.2	0.060	2	DEC 8	DEC 28	637	0.06	12040.	55454.	1.511	0.	1.22	0.	2.728	2.263
31	NAT13	100.0	85.0	0.150	1	OCT 6	NOV 2	530	0.05	12311.	41818.	2.046	0.	0.59	0.	2.633	3.975
32	NAT14	100.0	85.0	0.150	1	JUN 2	JUN 29	473	0.04	12277.	37766.	1.843	0.	0.59	0.	2.434	3.975
27	NAT9	50.0	43.0	0.140	1	MAR 31	APR 20	418	0.04	14025.	17738.	0.992	0.	0.30	0.	1.287	3.975
28	NAT10	50.0	43.0	0.140	1	NOV 3	NOV 23	401	0.04	14037.	16931.	0.945	0.	0.29	0.	1.240	3.975
29	NAT11	50.0	43.0	0.140	1	APR 21	MAY 11	358	0.03	14033.	15182.	0.847	0.	0.29	0.	1.141	3.975
30	NAT12	50.0	43.0	0.140	1	JUL 14	AUG 3	326	0.03	14033.	13712.	0.765	0.	0.29	0.	1.059	3.975
25	NAT7	25.0	22.3	0.110	1	JUL 14	JUL 27	295	0.03	14522.	6472.	0.374	0.	0.15	0.	0.520	3.975
26	NAT8	25.0	22.3	0.110	1	MAY 19	JUN 1	279	0.03	14518.	6176.	0.356	0.	0.15	0.	0.503	3.975
21	NAT3	25.0	22.3	0.110	1	JUL 14	JUL 27	267	0.03	14519.	5854.	0.338	0.	0.15	0.	0.485	3.975
22	NAT4	25.0	22.3	0.110	1	NOV 17	NOV 30	255	0.03	14510.	5646.	0.326	0.	0.15	0.	0.472	3.975
23	NAT5	25.0	22.3	0.110	1	MAY 12	MAY 25	248	0.02	14518.	5467.	0.315	0.	0.15	0.	0.462	3.975
24	NAT6	25.0	22.3	0.110	1	SEP 8	SEP 21	237	0.02	14514.	5241.	0.302	0.	0.15	0.	0.449	3.975
19	NAT1	25.0	22.3	0.110	1	JUL 14	JUL 27	230	0.02	14506.	5142.	0.296	0.	0.15	0.	0.443	3.975
20	NAT2	25.0	22.3	0.110	1	JUL 14	JUL 27	229	0.02	14517.	5067.	0.292	0.	0.15	0.	0.439	3.975
	TIEAID										88382.	0.530				0.530	6.000
	THERMAL TOTALS										27850936.	406.826	0.	63.83	0.	470.653	
	PRESENT VALUE OF TOTALS											383.798	0.	60.22	0.	444.017	

Arthur D Little, Inc.

CLOTHES DRYERS (AIR) COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06
OPERATION + MAINTENANCE INFLATION FACTOR	0.03
PEAK LOAD (MW)	6075.60
THERMAL PEAK (MW)	5490.00

SPINNING RESERVE REQUIREMENT	0.
NIGHTLY PEAK LOAD ADDER (MW)	0.
MAXIMUM CAPACITY (MW)	6400.00
CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5	JUN 8	6437	0.73	9500.	3206539.	40.361	0.	5.21	0.	45.571	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 3	DEC 7	6751	0.76	9600.	2679190.	34.076	0.	4.63	0.	38.708	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26	JUN 29	6750	0.76	9600.	2670060.	33.962	0.	4.62	0.	38.586	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.70	9306.	4947865.	104.213	0.	8.26	0.	112.477	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3	MAR 30	6351	0.70	9713.	1840652.	23.688	0.	4.14	0.	27.829	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 8	OCT 5	6229	0.69	10010.	1217336.	16.145	0.	3.10	0.	19.244	1.325
8	COAL6	200.0	200.0	0.070	3	JUL 28	AUG 24	5894	0.64	10030.	1123537.	14.930	0.	3.01	0.	17.943	1.325
3	COAL3	100.0	100.0	0.060	3	AUG 4	AUG 24	5516	0.60	12023.	523362.	8.345	0.	1.71	0.	10.051	1.325
4	COAL4	100.0	100.0	0.060	3	DEC 8	DEC 28	5103	0.54	12038.	476189.	7.595	0.	1.66	0.	9.251	1.325
2	COAL2	100.0	109.1	0.060	3	OCT 6	OCT 26	4758	0.51	12023.	446628.	7.114	0.	1.63	0.	8.740	1.325
1	COAL1	100.0	100.0	0.060	3	MAR 31	APR 20	4477	0.47	12041.	410541.	6.549	0.	1.59	0.	8.137	1.325
16	OIL66	600.0	600.0	0.220	2	AUG 25	SEP 28	3941	0.32	9474.	1674395.	35.905	0.	3.88	0.	39.783	2.263
15	OIL65	500.0	500.0	0.190	2	AUG 4	SEP 7	2317	0.18	9600.	795673.	17.288	0.	3.25	0.	20.542	2.263
11	OIL64	300.0	300.0	0.100	2	DEC 1	DEC 28	1334	0.12	9318.	312168.	6.937	0.	2.72	0.	9.661	2.263
9	OIL63	200.0	199.7	0.070	2	APR 28	MAY 25	904	0.08	10131.	146583.	3.361	0.	2.11	0.	5.468	2.263
5	OIL61	100.0	99.7	0.060	2	OCT 27	NOV 16	670	0.06	12083.	56148.	1.536	0.	1.22	0.	2.753	2.263
6	OIL62	100.0	96.9	0.060	2	APR 7	APR 27	541	0.05	12056.	46960.	1.281	0.	1.21	0.	2.490	2.263
31	NAT13	100.0	85.0	0.150	1	MAR 3	MAR 30	470	0.04	12379.	36118.	1.777	0.	0.59	0.	2.368	3.975
32	NAT14	100.0	85.0	0.150	1	OCT 6	NOV 2	397	0.04	12293.	31419.	1.535	0.	0.59	0.	2.124	3.975
27	NAT9	50.0	43.0	0.140	1	SEP 8	SEP 28	353	0.03	14056.	14743.	0.824	0.	0.29	0.	1.118	3.975
28	NAT10	50.0	43.0	0.140	1	JUN 9	JUN 29	311	0.03	14042.	13097.	0.731	0.	0.29	0.	1.025	3.975
29	NAT11	50.0	43.0	0.140	1	NOV 10	NOV 30	277	0.03	14028.	11770.	0.656	0.	0.29	0.	0.950	3.975
30	NAT12	50.0	43.0	0.140	1	AUG 4	AUG 24	259	0.02	14030.	10934.	0.610	0.	0.29	0.	0.903	3.975
25	NAT7	25.0	22.2	0.110	1	DEC 15	DEC 28	241	0.02	14522.	5297.	0.306	0.	0.15	0.	0.452	3.975
26	NAT8	25.0	22.2	0.110	1	JUN 16	JUN 29	227	0.02	14538.	4978.	0.288	0.	0.15	0.	0.434	3.975
21	NAT3	25.0	22.2	0.110	1	DEC 8	DEC 21	205	0.02	14513.	4550.	0.262	0.	0.15	0.	0.409	3.975
22	NAT4	25.0	22.2	0.110	1	NOV 17	NOV 30	202	0.02	14522.	4471.	0.258	0.	0.15	0.	0.404	3.975
23	NAT5	25.0	22.2	0.110	1	JUN 9	JUN 22	193	0.02	14520.	4266.	0.246	0.	0.15	0.	0.392	3.975
24	NAT6	25.0	22.2	0.110	1	SEP 15	SEP 28	185	0.02	14516.	4088.	0.236	0.	0.15	0.	0.382	3.975
19	NAT1	25.0	22.2	0.110	1	NOV 17	NOV 30	179	0.02	14515.	3980.	0.230	0.	0.15	0.	0.376	3.975
20	NAT2	25.0	22.2	0.110	1	SEP 8	SEP 21	173	0.02	14517.	3854.	0.222	0.	0.15	0.	0.368	3.975
	TIEAID										60466.	0.363				0.363	6.000
	THERMAL TOTALS										27840114.	405.298	0.	63.87	0.	469.164	
	PRESENT VALUE OF TOTALS											382.357	0.	60.25	0.	442.608	

ANNUAL LOAD ENERGY (MWHRS) 33110514.

Arthur D Little, Inc.

DISHWASHERS (HEATERS) COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	6087.80	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5490.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM - THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16 AUG 3	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5 JUN 3	6437	0.73	9501.	3197092.	40.245	0.	5.20	0.	45.443	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 3 DEC 7	6751	0.76	9601.	2677577.	34.058	0.	4.63	0.	38.689	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26 JUN 29	6750	0.76	9602.	2669539.	33.960	0.	4.62	0.	38.583	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2 JUN 15	6505	0.70	9307.	4931439.	103.877	0.	8.25	0.	112.130	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3 MAR 30	6197	0.68	9715.	1790036.	23.041	0.	4.09	0.	27.136	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 8 OCT 5	6159	0.68	10014.	1193567.	15.902	0.	3.08	0.	18.984	1.325
3	COAL6	200.0	200.0	0.070	3	JUL 28 AUG 24	5755	0.63	10023.	1104983.	14.673	0.	3.00	0.	17.663	1.325
3	COAL3	100.0	100.0	0.060	3	DEC 8 DEC 28	5306	0.58	12012.	510426.	8.123	0.	1.69	0.	9.815	1.325
4	COAL4	100.0	100.0	0.060	3	OCT 27 NOV 16	5096	0.55	12026.	430455.	7.655	0.	1.66	0.	9.316	1.325
2	COAL2	100.0	100.0	0.060	3	OCT 6 OCT 26	4769	0.50	12039.	439946.	7.017	0.	1.62	0.	8.636	1.325
1	COAL1	100.0	100.0	0.060	3	AUG 4 AUG 24	4534	0.47	12040.	416275.	6.640	0.	1.59	0.	8.234	1.325
16	OIL66	600.0	600.0	0.220	2	AUG 25 SEP 23	3890	0.32	9466.	1696974.	36.356	0.	3.89	0.	40.250	2.263
15	OIL65	500.0	500.0	0.190	2	AUG 4 SEP 7	2432	0.19	9595.	838773.	18.216	0.	3.29	0.	21.505	2.263
11	OIL64	300.0	300.0	0.100	2	DEC 1 DEC 28	1428	0.13	9826.	336057.	7.474	0.	2.75	0.	10.220	2.263
9	OIL63	200.0	200.0	0.070	2	APR 28 MAY 25	935	0.09	10113.	162688.	3.724	0.	2.12	0.	5.846	2.263
5	OIL61	100.0	100.6	0.060	2	MAR 31 APR 20	742	0.07	12059.	63646.	1.737	0.	1.23	0.	2.963	2.263
6	OIL62	100.0	97.0	0.060	2	SEP 8 SEP 28	624	0.06	12044.	54533.	1.487	0.	1.22	0.	2.703	2.263
31	NAT13	100.0	85.0	0.150	1	MAR 3 MAR 30	528	0.05	12343.	41003.	2.012	0.	0.59	0.	2.604	3.975
32	NAT14	100.0	85.0	0.150	1	NOV 3 NOV 30	458	0.04	12291.	36455.	1.781	0.	0.59	0.	2.372	3.975
27	NAT9	50.0	43.0	0.140	1	JUN 9 JUN 29	414	0.04	14040.	17427.	0.973	0.	0.30	0.	1.268	3.975
23	NAT10	50.0	43.0	0.140	1	AUG 4 AUG 24	372	0.04	14037.	15702.	0.876	0.	0.29	0.	1.171	3.975
29	NAT11	50.0	43.0	0.140	1	OCT 6 OCT 26	336	0.03	14036.	14203.	0.793	0.	0.29	0.	1.087	3.975
30	NAT12	50.0	43.0	0.140	1	DEC 8 DEC 28	303	0.03	14028.	12788.	0.713	0.	0.29	0.	1.007	3.975
25	NAT7	25.0	22.2	0.110	1	JUN 9 JUN 22	282	0.03	14518.	6241.	0.360	0.	0.15	0.	0.507	3.975
26	NAT8	25.0	22.2	0.110	1	AUG 4 AUG 17	266	0.03	14529.	5835.	0.337	0.	0.15	0.	0.484	3.975
21	NAT3	25.0	22.2	0.110	1	JUN 16 JUN 29	243	0.02	14512.	5386.	0.311	0.	0.15	0.	0.457	3.975
22	NAT4	25.0	22.2	0.110	1	APR 14 APR 27	237	0.02	14510.	5244.	0.302	0.	0.15	0.	0.449	3.975
23	NAT5	25.0	22.2	0.110	1	OCT 20 NOV 2	232	0.02	14519.	5130.	0.296	0.	0.15	0.	0.443	3.975
24	NAT6	25.0	22.2	0.110	1	NOV 17 NOV 30	223	0.02	14520.	4938.	0.285	0.	0.15	0.	0.431	3.975
19	NAT1	25.0	22.2	0.110	1	APR 14 APR 27	211	0.02	14507.	4713.	0.272	0.	0.15	0.	0.418	3.975
20	NAT2	25.0	22.2	0.110	1	JUN 9 JUN 22	211	0.02	14512.	4693.	0.271	0.	0.15	0.	0.417	3.975
	TIEAID									77767.	0.467				0.467	6.000
	THERMAL TOTALS									27878328.	407.702	0.	63.86	0.	471.566	
	PRESENT VALUE OF TOTALS										334.624	0.	60.25	0.	444.874	

Arthur D Little, Inc.

CLOTHES DRYERS (MOTORS) COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06
OPERATION + MAINTENANCE INFLATION FACTOR	0.03
PEAK LOAD (MW)	6093.90
THERMAL PEAK (MW)	5508.00

SPINNING RESERVE REQUIREMENT	0.
NIGHTLY PEAK LOAD ADDER (MW)	0.
MAXIMUM CAPACITY (MW)	6400.00
CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	- THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5	JUN 8	6437	0.73	9502.	3193744.	40.205	0.	5.20	0.	45.405	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 3	DEC 7	6751	0.76	9601.	2671642.	33.986	0.	4.63	0.	38.611	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26	JUN 29	6750	0.76	9602.	2662416.	33.872	0.	4.62	0.	38.490	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.70	9308.	4910302.	103.446	0.	8.24	0.	111.684	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3	MAR 30	6177	0.68	9718.	1779206.	22.909	0.	4.08	0.	26.993	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 8	OCT 5	6121	0.68	10017.	1187709.	15.763	0.	3.07	0.	18.835	1.325
8	COAL6	200.0	200.0	0.070	3	JUL 28	AUG 24	5696	0.62	10020.	1097207.	14.566	0.	2.99	0.	17.554	1.325
3	COAL3	100.0	100.0	0.060	3	AUG 4	AUG 24	5409	0.59	12013.	518504.	8.253	0.	1.70	0.	9.953	1.325
4	COAL4	100.0	100.0	0.060	3	DEC 8	DEC 23	5038	0.54	12026.	476120.	7.536	0.	1.66	0.	9.242	1.325
2	COAL2	100.0	100.0	0.060	3	OCT 6	OCT 26	4732	0.50	12036.	438144.	6.987	0.	1.62	0.	8.603	1.325
1	COAL1	100.0	100.0	0.060	3	MAR 31	APR 20	4373	0.46	12038.	403525.	6.436	0.	1.58	0.	8.016	1.325
16	OIL66	600.0	600.0	0.220	2	AUG 25	SEP 23	3874	0.33	9460.	1731246.	37.068	0.	3.92	0.	40.985	2.263
15	OIL65	500.0	500.0	0.190	2	AUG 4	SEP 7	2490	0.19	9598.	854127.	18.555	0.	3.30	0.	21.856	2.263
11	OIL64	300.0	300.0	0.100	2	DEC 1	DEC 28	1463	0.13	9830.	342674.	7.624	0.	2.75	0.	10.377	2.263
9	OIL63	200.0	200.0	0.070	2	APR 28	MAY 25	1002	0.10	10102.	167664.	3.833	0.	2.13	0.	5.960	2.263
5	OIL61	100.0	100.5	0.060	2	OCT 27	NOV 16	772	0.08	12055.	66012.	1.801	0.	1.23	0.	3.029	2.263
6	OIL62	100.0	96.3	0.060	2	SEP 8	SEP 28	625	0.06	12038.	54968.	1.498	0.	1.22	0.	2.714	2.263
31	NAT13	100.0	85.0	0.150	1	MAR 31	APR 27	537	0.05	12277.	42702.	2.084	0.	0.59	0.	2.676	3.975
32	NAT14	100.0	85.0	0.150	1	JUN 9	JUL 6	484	0.04	12323.	37921.	1.857	0.	0.59	0.	2.448	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 10	NOV 30	417	0.04	14034.	17629.	0.933	0.	0.30	0.	1.278	3.975
28	NAT10	50.0	43.0	0.140	1	MAR 3	MAR 23	384	0.04	14047.	16150.	0.902	0.	0.29	0.	1.196	3.975
29	NAT11	50.0	43.0	0.140	1	OCT 6	OCT 26	329	0.03	14016.	14121.	0.787	0.	0.29	0.	1.081	3.975
30	NAT12	50.0	43.0	0.140	1	AUG 4	AUG 24	314	0.03	14032.	13345.	0.744	0.	0.29	0.	1.038	3.975
25	NAT7	25.0	22.2	0.110	1	OCT 27	NOV 9	292	0.03	14514.	6466.	0.373	0.	0.15	0.	0.520	3.975
26	NAT8	25.0	22.3	0.110	1	DEC 8	DEC 21	282	0.03	14519.	6232.	0.360	0.	0.15	0.	0.506	3.975
21	NAT3	25.0	22.3	0.110	1	DEC 15	DEC 28	263	0.03	14512.	5814.	0.335	0.	0.15	0.	0.482	3.975
22	NAT4	25.0	22.3	0.110	1	MAR 17	MAR 30	258	0.03	14516.	5712.	0.330	0.	0.15	0.	0.476	3.975
23	NAT5	25.0	22.2	0.110	1	OCT 20	NOV 2	245	0.02	14525.	5397.	0.312	0.	0.15	0.	0.458	3.975
24	NAT6	25.0	22.3	0.110	1	NOV 17	NOV 30	235	0.02	14520.	5142.	0.297	0.	0.15	0.	0.443	3.975
19	NAT1	25.0	22.3	0.110	1	NOV 17	NOV 30	223	0.02	14508.	4955.	0.286	0.	0.15	0.	0.432	3.975
20	NAT2	25.0	22.3	0.110	1	DEC 8	DEC 21	219	0.02	14519.	4836.	0.279	0.	0.15	0.	0.425	3.975
	TIEAID										82089.	0.493				0.493	6.000
THERMAL TOTALS											27875430.	408.275	0.	63.85	0.	472.124	
PRESENT VALUE OF TOTALS												385.165	0.	60.24	0.	445.400	

ANNUAL LOAD ENERGY (MWHRS) 33145830.

CLOTHES WASHERS (MOTORS) COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	6093.90	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5508.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5	JUN 8	6437	0.73	9502.	3192711.	40.193	0.	5.20	0.	45.392	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 3	DEC 7	6751	0.76	9602.	2671042.	33.978	0.	4.63	0.	38.604	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26	JUN 29	6750	0.76	9602.	2660776.	33.851	0.	4.62	0.	38.468	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6595	0.70	9308.	4902450.	103.285	0.	8.23	0.	111.517	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3	MAR 30	6179	0.68	9718.	1780983.	22.931	0.	4.09	0.	27.017	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 8	OCT 5	6105	0.67	10017.	1134508.	15.721	0.	3.07	0.	18.790	1.325
8	COAL6	200.0	200.0	0.070	3	JUL 28	AUG 24	5672	0.62	10020.	1091965.	14.497	0.	2.98	0.	17.480	1.325
3	COAL3	100.0	100.0	0.060	3	AUG 4	AUG 24	5406	0.59	12013.	518494.	8.252	0.	1.70	0.	9.953	1.325
4	COAL4	100.0	100.0	0.060	3	DEC 8	DEC 28	5021	0.54	12027.	474164.	7.555	0.	1.65	0.	9.209	1.325
2	COAL2	100.0	100.0	0.060	3	OCT 6	OCT 26	4693	0.50	12031.	436763.	6.962	0.	1.61	0.	8.577	1.325
1	COAL1	100.0	100.0	0.060	3	MAR 31	APR 20	4375	0.46	12038.	403774.	6.440	0.	1.58	0.	8.020	1.325
16	OIL66	600.0	600.0	0.220	2	AUG 25	SEP 23	3873	0.33	9459.	1734512.	37.135	0.	3.92	0.	41.054	2.263
15	OIL65	500.0	500.0	0.190	2	AUG 4	SEP 7	2500	0.20	9597.	850997.	18.659	0.	3.31	0.	21.964	2.263
11	OIL64	300.0	300.0	0.100	2	DEC 1	DEC 28	1477	0.13	9834.	344239.	7.662	0.	2.75	0.	10.415	2.263
9	OIL63	200.0	200.0	0.070	2	APR 28	MAY 25	993	0.09	10100.	166116.	3.797	0.	2.12	0.	5.922	2.263
5	OIL61	100.0	100.0	0.060	2	OCT 27	NOV 16	764	0.07	12051.	65673.	1.791	0.	1.23	0.	3.019	2.263
6	OIL62	100.0	96.0	0.060	2	SEP 8	SEP 23	630	0.06	12044.	54815.	1.494	0.	1.22	0.	2.711	2.263
31	NAT13	100.0	85.0	0.150	1	MAR 31	APR 27	533	0.05	12232.	42132.	2.057	0.	0.59	0.	2.649	3.975
32	NAT14	100.0	85.0	0.150	1	JUN 9	JUL 6	481	0.04	12331.	37534.	1.840	0.	0.59	0.	2.431	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 10	NOV 30	419	0.04	14040.	17576.	0.931	0.	0.30	0.	1.276	3.975
28	NAT10	50.0	43.0	0.140	1	MAR 3	MAR 23	377	0.04	14047.	15835.	0.887	0.	0.29	0.	1.182	3.975
29	NAT11	50.0	43.0	0.140	1	OCT 6	OCT 26	331	0.03	14023.	14085.	0.785	0.	0.29	0.	1.079	3.975
30	NAT12	50.0	43.0	0.140	1	AUG 4	AUG 24	310	0.03	14028.	13097.	0.730	0.	0.29	0.	1.024	3.975
25	NAT7	25.0	22.2	0.110	1	OCT 27	NOV 9	283	0.03	14515.	6359.	0.367	0.	0.15	0.	0.514	3.975
26	NAT8	25.0	22.2	0.110	1	DEC 8	DEC 21	273	0.03	14519.	6119.	0.353	0.	0.15	0.	0.500	3.975
21	NAT3	25.0	22.2	0.110	1	DEC 15	DEC 23	259	0.03	14514.	5734.	0.331	0.	0.15	0.	0.477	3.975
22	NAT4	25.0	22.2	0.110	1	MAR 17	MAR 30	252	0.03	14512.	5612.	0.324	0.	0.15	0.	0.470	3.975
23	NAT5	25.0	22.2	0.110	1	OCT 20	NOV 2	243	0.02	14528.	5357.	0.309	0.	0.15	0.	0.456	3.975
24	NAT6	25.0	22.2	0.110	1	NOV 17	NOV 30	232	0.02	14520.	5071.	0.293	0.	0.15	0.	0.439	3.975
19	NAT1	25.0	22.2	0.110	1	NOV 17	NOV 30	221	0.02	14509.	4867.	0.281	0.	0.15	0.	0.427	3.975
20	NAT2	25.0	22.2	0.110	1	DEC 8	DEC 21	214	0.02	14510.	4763.	0.275	0.	0.15	0.	0.421	3.975
	TIEAID										78978.	0.474				0.474	6.000
THERMAL TOTALS											27856872.	407.957	0.	63.84	0.	471.795	
PRESENT VALUE OF TOTALS												384.866	0.	60.22	0.	445.089	

DISHWASHERS (MOTORS) COST CASE FOR WINTER PEAKING UTILITY

1980 ANNUAL PRODUCTION COST SUMMARY

PRESENT VALUE INTEREST RATE	0.06	SPINNING RESERVE REQUIREMENT	0.
OPERATION + MAINTENANCE INFLATION FACTOR	0.03	NIGHTLY PEAK LOAD ADDER (MW)	0.
PEAK LOAD (MW)	6093.90	MAXIMUM CAPACITY (MW)	6400.00
THERMAL PEAK (MW)	5508.00	CONTINUOUS CAPACITY (MW)	6400.00

ALL COSTS GIVEN IN MILLIONS OF DOLLARS

ID. NO.	NAME OF UNIT	MAX. CAP. (MW)	MAX. LOAD (MW)	FORCD OUTGE RATE	MIN. DOWN TIME	PLANNED MAINTENANCE FROM	THRU	HRS. ON LINE	CAP. FAC.	AVG. OPER. HT.RT.	ENERGY OUTPUT (MWHRS)	FUEL COST	START UP COST	OPER/ MAINT COST	FUEL INV. COST	TOTAL COST	FUEL PRICE $/MBTU
18	NUC1	800.0	800.0	0.170	168	JUN 16	AUG 3	6319	0.72	10001.	5051712.	33.468	0.	6.39	0.	39.862	0.662
14	COAL10	500.0	500.0	0.190	168	MAY 5	JUN 8	6437	0.73	9502.	3188575.	40.143	0.	5.20	0.	45.339	1.325
12	COAL8	400.0	400.0	0.150	168	NOV 3	DEC 7	6751	0.76	9602.	2668993.	33.954	0.	4.62	0.	33.577	1.325
13	COAL9	400.0	400.0	0.150	168	MAY 26	JUN 29	6750	0.76	9603.	2657797.	33.814	0.	4.61	0.	33.428	1.325
17	OIL67	800.0	800.0	0.230	168	JUN 2	JUN 15	6505	0.70	9309.	4903568.	103.311	0.	8.23	0.	111.545	2.263
10	COAL7	300.0	300.0	0.100	3	MAR 3	MAR 30	6123	0.67	9714.	1774934.	22.843	0.	4.08	0.	26.924	1.325
7	COAL5	200.0	200.0	0.070	3	SEP 8	OCT 5	6034	0.67	10015.	1173572.	15.572	0.	3.06	0.	18.631	1.325
8	COAL6	200.0	200.0	0.070	3	JUL 28	AUG 24	5639	0.62	10017.	1083674.	14.448	0.	2.98	0.	17.429	1.325
3	COAL3	100.0	100.0	0.060	3	DEC 8	DEC 28	5293	0.58	12012.	508211.	8.088	0.	1.69	0.	9.778	1.325
4	COAL4	100.0	100.0	0.060	3	OCT 27	NOV 16	5041	0.54	12026.	475935.	7.584	0.	1.66	0.	9.240	1.325
2	COAL2	100.0	100.0	0.060	3	OCT 6	OCT 26	4713	0.50	12033.	438379.	6.989	0.	1.62	0.	8.605	1.325
1	COAL1	100.0	100.0	0.060	3	AUG 4	AUG 24	4514	0.48	12037.	418690.	6.677	0.	1.60	0.	8.273	1.325
16	OIL66	600.0	600.0	0.220	2	AUG 25	SEP 28	3883	0.33	9458.	1745560.	37.369	0.	3.93	0.	41.295	2.263
15	OIL65	500.0	500.0	0.190	2	AUG 4	SEP 7	2503	0.20	9595.	863304.	18.749	0.	3.31	0.	22.058	2.263
11	OIL64	300.0	300.0	0.100	2	DEC 1	DEC 28	1495	0.13	9835.	348293.	7.753	0.	2.76	0.	10.511	2.263
9	OIL63	200.0	200.0	0.070	2	APR 28	MAY 25	1017	0.10	10108.	169694.	3.882	0.	2.13	0.	6.010	2.263
5	OIL61	100.0	100.4	0.060	2	MAR 31	APR 20	777	0.08	12041.	67776.	1.847	0.	1.23	0.	3.077	2.263
6	OIL62	100.0	97.0	0.060	2	SEP 8	SEP 28	661	0.07	12044.	57473.	1.567	0.	1.22	0.	2.786	2.263
31	NAT13	100.0	85.0	0.150	1	JUN 9	JUL 6	554	0.05	12267.	44140.	2.152	0.	0.59	0.	2.745	3.975
32	NAT14	100.0	85.0	0.150	1	MAR 3	MAR 30	480	0.04	12270.	38334.	1.870	0.	0.59	0.	2.461	3.975
27	NAT9	50.0	43.0	0.140	1	NOV 10	NOV 30	431	0.04	14022.	18449.	1.023	0.	0.30	0.	1.324	3.975
28	NAT10	50.0	43.0	0.140	1	AUG 4	AUG 24	410	0.04	14039.	17309.	0.966	0.	0.30	0.	1.261	3.975
29	NAT11	50.0	43.0	0.140	1	OCT 6	OCT 26	361	0.03	14029.	15274.	0.852	0.	0.29	0.	1.146	3.975
30	NAT12	50.0	43.0	0.140	1	DEC 8	DEC 28	331	0.03	14045.	13910.	0.777	0.	0.29	0.	1.071	3.975
25	NAT7	25.0	22.3	0.110	1	NOV 17	NOV 30	296	0.03	14516.	6527.	0.377	0.	0.15	0.	0.523	3.975
26	NAT8	25.0	22.3	0.110	1	AUG 4	AUG 17	283	0.03	14514.	6263.	0.362	0.	0.15	0.	0.503	3.975
21	NAT3	25.0	22.3	0.110	1	NOV 17	NOV 30	271	0.03	14516.	5999.	0.346	0.	0.15	0.	0.493	3.975
22	NAT4	25.0	22.3	0.110	1	OCT 27	NOV 9	263	0.03	14513.	5813.	0.335	0.	0.15	0.	0.482	3.975
23	NAT5	25.0	22.3	0.110	1	APR 14	APR 27	253	0.03	14524.	5585.	0.322	0.	0.15	0.	0.469	3.975
24	NAT6	25.0	22.3	0.110	1	OCT 20	NOV 2	239	0.02	14511.	5317.	0.307	0.	0.15	0.	0.453	3.975
19	NAT1	25.0	22.3	0.110	1	NOV 17	NOV 30	236	0.02	14511.	5242.	0.302	0.	0.15	0.	0.449	3.975
20	NAT2	25.0	22.3	0.110	1	APR 14	APR 27	232	0.02	14514.	5109.	0.295	0.	0.15	0.	0.441	3.975
	TIEAID										89133.	0.535				0.535	6.000
THERMAL TOTALS											27883602.	408.882	0.	63.85	0.	472.729	
PRESENT VALUE OF TOTALS												385.738	0.	60.23	0.	445.970	

APPENDIX D

MONTHLY PRODUCTION SIMULATION PROGRAM

PROGRAM DESCRIPTION MANUAL (MPS)

FOR SIMULATING THE OPERATION OF A GENERATING SYSTEM TO DETERMINE THE PRODUCTION COSTS.

SYSTEM PLANNING SECTION

JANUARY 1977

ELECTRIC UTILITY SYSTEMS ENGINEERING

GENERAL ELECTRIC COMPANY

SCHENECTADY, NEW YORK

INTRODUCTION

The Monthly Production Simulation (MPS) program is designed to simulate the operation of the generation system of an electric utility on a chronological hourly basis. The program combines a model of future customer load demands and a model of each generator's performance characteristics with rules for area protection, spinning reserve and unit commitment to analyze a variety of planning and operation strategies.

I. SCOPE OF PROGRAM

The production cost simulation program is designed to simulate the operation of an electric power generation system in order to determine the operating expense that will be incurred. The chief component of this expense is fuel cost, though other items such as operating and maintenance labor and startup costs do contribute. As currently compiled, a maximum of 150 thermal units may be considered. Costs are summarized on a monthly and on an annual basis. The annual results are adjusted using present worth techniques to obtain a single cost figure that may be assigned to the plan under study.

This program has three particular areas of application. The first is in the field of generation - transmission planning studies and these studies are characterized by:

- 20-30 year periods are examined
- Maintenance schedules are set by the program
- Rapid running speed is essential
- Many alternates are examined
- Annual output only is required

The second area in which this program is used is to assist in the financial simulation of the operations of an electric utility company. Here, production expense is but one item being considered, yet its magnitude makes it essential that a most accurate simulation be made. The requirements for this are very similar to those for generation transmission planning except that monthly output is required as these studies are conducted on a calendar month basis.

The third area in which this program has been used is for the preparation of annual fuel budget estimates. Unlike the first two applications described, fuel budget estimation is characterized by:

- 1-3 year periods are analyzed
- Maintenance schedules are read in as input
- Speed is secondary to simulation detail
- Relatively few alternates are studied
- Monthly summaries are required

This program can operate successfully in all three areas though the mechanics of program operation are necessarily different in each case.

Running time is, naturally, dependent on the detail of the simulation, so that fuel budgeting studies tend to require more running time per year studied than do studies in the other two areas. The reasons for this will be discussed in subsequent sections.

The program permits the study of system performance and cost under a variety of planning alternatives and operating policies. To do this, three basic items of input are required:

- A system load model
- A system capacity model
- A definition of operating policy

Some of the principal features of this program are as follows:

- The load model is an ordered sequence of the hour-by-hour loads expected for the system. Such representation is required if the economic effects of unit starts and pumped storage hydro are to be represented accurately.
- Thermal units are dispatched on an equal incremental cost basis making use of step incremental representation.
- The variable portion of the O&M expense can be included during the commitment and dispatch. Generator costs are not effected, however generator dispatch is altered by the inclusion of this option.
- All forms of hydro can be considered, run-of-river, pondage, and pumped storage.
- Maintenance schedules are set up on a weekly basis and the cyclical nature of each units maintenance pattern is considered.
- Contractual purchases and sales can be simulated.
- Penalty factors can be incorporated into the dispatch if this is desired.
- A stochastic simulation of generator forced outage is provided.
- Load uncertainty can be considered.
- Multi-state analysis can be included.

In the material that follows, the techniques used by the program will be described first. This will be followed by a description of the input data forms, and finally, an illustrative problem will be done to show how the forms would be filled out and the output that results therefrom.

II. Program Techniques

In order to understand the overall logic followed by this program, a simplified flow chart outlining the steps taken by the program is shown as Figure D-1. This diagram illustrates the program data input options and indicates the major subroutines of the program and their sequencing.

Input Read-In Options

The program has three input read-in options. The first of these is the annual option. Here data is read in at the beginning of the year and at no other time. This option permits additions and retirements at any time during the year by means of an input made at the start of the year.

Note that it is possible to advance through a year updating maintenance patterns and increasing inflation multipliers without doing any further calculations. This feature permits re-running an expansion from a given year forward without calculating the preceding years. This option is the one most commonly used in long range expansion studies.

The second option is called modified annual. This option permits reading input at the start of the year and also at the start of selected months of the year. The primary purpose of this option is to permit general data to be changed during the year if desired. An example of when this option would be required would be the simulation of a contract that required fuel prices to change at some time other than the first of the year.

The third and last option is the monthly option. This option requires data to be read in not only at the first of the year but also at the beginning of every month. This option is intended for short range fuel budget estimation studies and may be used for example to simulate weekend maintenance shutdowns that cannot be done with annual option. It is a requirement of the monthly input option that data be provided for all months.

Sequence of Calculations

The following describes the functions performed by the program and the sequence of their execution. Figure D-1 shows the major subroutines of the program and their logical relationship to one another.

Read General Data	-	At this point all general data required by the program is read in. These data define the load model, the capacity model and the operating rules for the system under study.

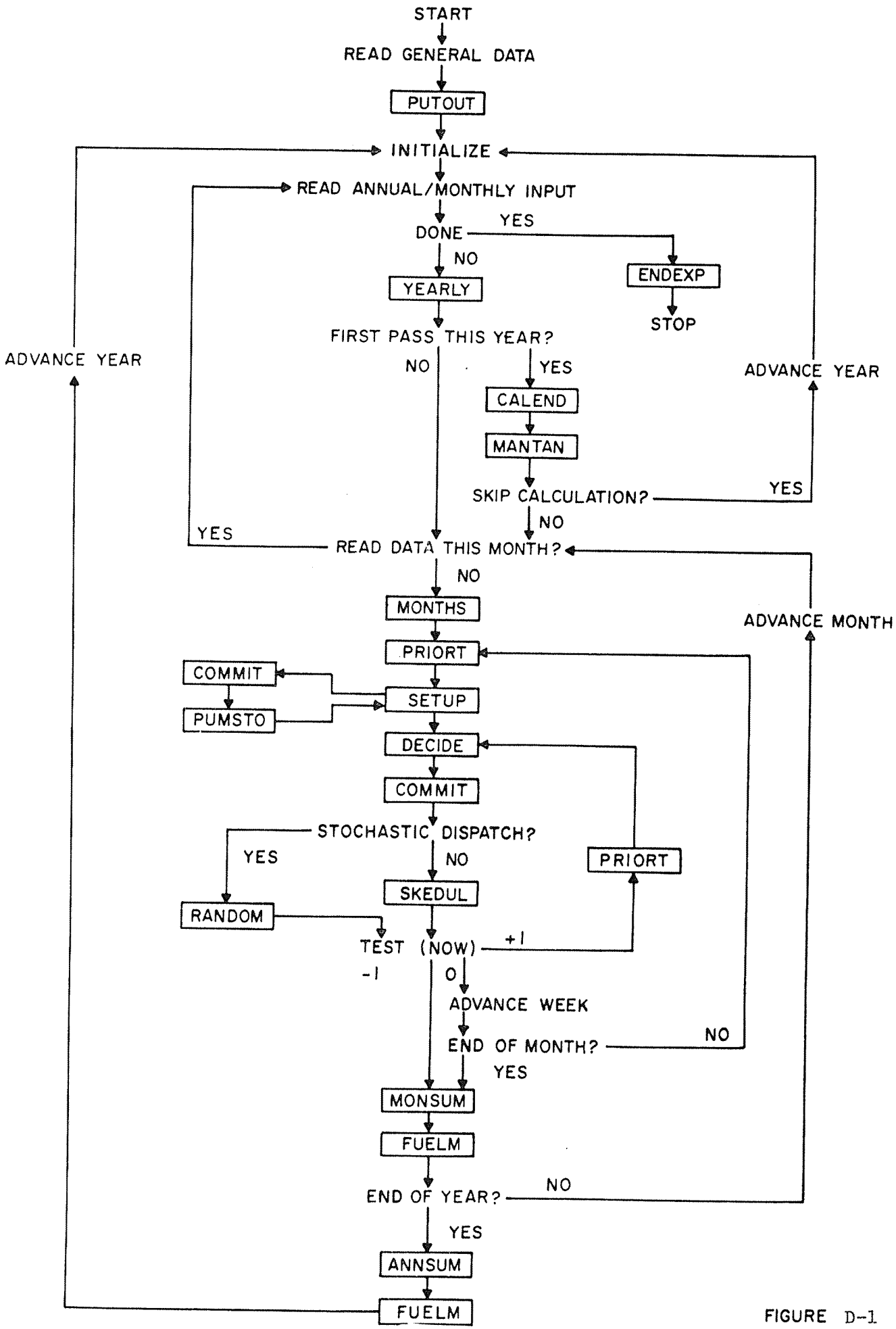

START
READ GENERAL DATA
PUTOUT
INITIALIZE
READ ANNUAL/MONTHLY INPUT
DONE
YES
NO
ENDEXP
STOP
YEARLY
FIRST PASS THIS YEAR?
NO
YES
CALEND
MANTAN
SKIP CALCULATION?
YES
NO
ADVANCE YEAR
ADVANCE YEAR
YES
READ DATA THIS MONTH?
NO
MONTHS
ADVANCE MONTH
PRIORT
COMMIT
PUMSTO
SETUP
DECIDE
COMMIT
STOCHASTIC DISPATCH?
YES
NO
PRIORT
SKEDUL
RANDOM
TEST (NOW)
+1
-1
0
ADVANCE WEEK
END OF MONTH?
NO
YES
MONSUM
FUELM
END OF YEAR?
NO
YES
ANNSUM
FUELM

FIGURE D-1

Subroutine-PUTOUT — This subroutine prints out all pertinent data necessary to establish a record of the input being used for the study. Typical output items are:

- Per-unit load model
- Capacity model for thermal system
- Hydro data
- Purchase and sale contracts
- Startup priority
- Maintenance cycle definition
- Generation types definition
- Fuel types definition
- Plant characteristics

Read Annual/Monthly Input - This is where annual input is read. In addition, as noted above, monthly data input can also be made at this point. Here, annual input is mandatory, monthly input is optional. The input here is in the nature of changes being made as the expansion progresses. Examples of annual/monthly input might be:

- Annual peak load
- Unit additions
- Unit retirements
- Fuel price changes
- Spinning reserve changes
- Monthly load energies to be met

Subroutine-ENDEXP — At the end of the expansion period this subroutine writes a set of comments noting the time of occurrence of any of the following:

- Spinning reserve deficiency
- Units loaded into emergency sections
- Pumped storage reservoir violation

- Pumped storage end-point violation

Normally none of these messages occur but the subroutine does afford the user a quick and mechanical check against abnormal system conditions.

Subroutine-YEARLY

The capacity model of the system is capable of being modified by this subroutine. Such modifications may be necessary due to:

- Unit additions and retirements
- Penalty factor changes
- Fuel cost changes
- Machine modifications
- Inflation

It should be noted that although this subroutine can be called in any month, changes due to inflation are made only at the beginning of the calendar year.

Subroutine-CALEND

Subroutine CALEND and several of the subroutines that follow operate on the per-unit load model and on the megawatt load model. (For a description of these models, refer to Figure D-2 of this text.)

This subroutine divides the year into calendar months and for each calendar month:

- Determines the sequence of day types that will be used to represent each month.
- Modifies this sequence to reflect holidays. This is done by considering that a holiday occurring during the week causes that day to be represented by a Saturday day type. A holiday occurring on a Saturday causes the preceeding Friday to be assigned a Saturday day type and a holiday occurring on a Sunday causes the following Monday to be assigned a Saturday day type. In order to do this it is necessary that the user state those days considered to be holidays for the system under study.
- Modifies daily load shapes to meet specified monthly load energies.

THE PER-UNIT LOAD MODEL

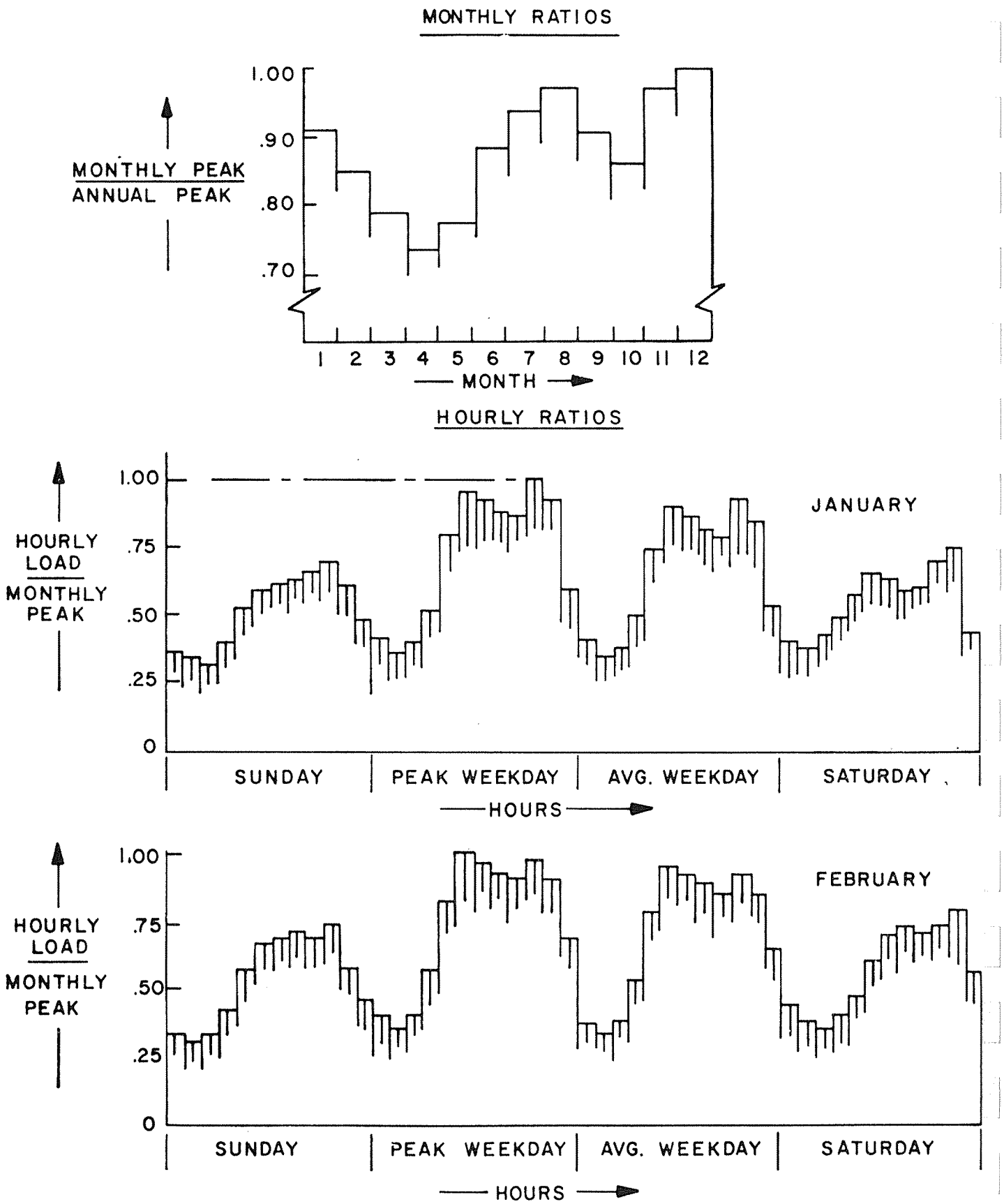


FIGURE D-2

Subroutine-MANTAN

Using the per-unit load model and the forecast annual peak, this subroutine determines the highest system load that will prevail for each week of the year. These peaks are then adjusted to reflect hydro, contractual purchases, and contractual sales. The resultant values represent the peak weekly loads that must be met by thermal generation.

This subroutine next examines the thermal maintenance requirements observing the cyclical pattern that each unit is following. The program develops a maintenance pattern that causes the thermal load plus thermal capacity on maintenance to be levelized insofar as this is possible. Units may be maintained only once a year, though the number of weeks of maintenance is a variable.

The program also has the capability to block out maintenance from any given week or weeks.

Subroutine MANTAN has the following features:

- Maintenance can be specified by input data, done automatically by the program, or a combination of both techniques may be used.
- The cyclical nature of each unit's maintenance pattern is considered.
- Unit additions and retirements are considered when developing the maintenance schedule.

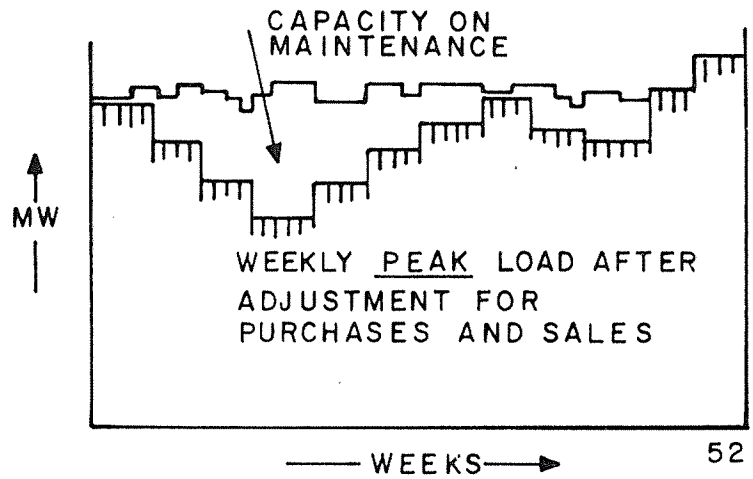
The overall effect of thermal maintenance and the use of the maintenance matrix to define the cyclical pattern of maintenance for a given unit is illustrated by Figure D-3.

Subroutine-MONTHS

Subroutine MONTHS develops the complete load cycles that will be used in simulating a particular month. These load cycles are then modified to consider run-of-river hydro, contractual purchases and contractual sales. After such modification, the resultant load pattern represents the load cycles to be served by the thermal generation of the system. In addition, the spinning reserve requirements that must be met by the thermal generation are developed by adjusting the system spinning reserve requirements to reflect the action of the pondage hydro and by the contractual purchases and sales. For example, if a pondage hydro plant is rated at 200 MW and in some hour the output of this plant has been scheduled to 150 MW by this subroutine, then a 50 MW spinning reserve credit may be taken at the users option. Similar

MAINTENANCE SCHEDULING

LEVELIZATION OF WEEKLY PEAKS PLUS CAPACITY ON MAINTENANCE



THE MAINTENANCE CYCLE AND AN EXAMPLE OF ITS USE

CYCLE

CYCLE YEAR	1	2	3	4	5	6	7	8	9	10
1	2	1	1	2	0	0	0	3	1	4
2	-1	1	2	0	0	0	1	2	3	-1
3		0	1	1	0	1	-1	-1	1	
4		1	1	1	1	-1			-1	
5		-1	1	-1	-1					
6			-1							
7										

← MAINTENANCE CYCLE MATRIX

	UNIT A	UNIT B
MAINTENANCE CYCLE	9	4
STARTING POINT IN CYCLE	1	2

YEAR	WEEKS OF MAINTENANCE /YEAR		
	UNIT A	UNIT B	
1970	1	X	← EXP. STARTS
1971	3	X	
1972	1	0	← UNIT B ADDED
1973	1	1	
1974	3	1	
1975	1	2	
1976	1	0	← EXP. ENDS

provisions prevail for contractual purchases and contractual sales. The way in which the subroutine develops schedules for pondage hydro, contractual purchases and contractual sales is shown by Figure D-4

Subroutine-PRIORT

This subroutine surveys the thermal units that are available for service and determines the order in which these units would be committed to the line as load rises and would be dropped from the line as load declines. In doing this, the subroutine makes use of a priority list which has been read in as input data or developed by the program.

In developing the priority order, the subroutine utilizes more than the read in priority list alone. For area protection, the program must also consider the minimum number of units that must always be on at each station. Program logic assigns the best units to service first at each plant until the required number are put on line and kept there as "must run" units. In making this choice "best" is interpreted to mean the first unit located at that plant that is encountered when descending the priority list.

Subroutine-SETUP

Subroutine SETUP lays out the hourly loads for the week, the load modifiers and the spinning reserve required. If any of the load modifiers are being curtailed in this week, consideration is made of this.

Next the question is asked if pumped storage hydro is present. If one or more plants are, it is then necessary to call subroutines COMMIT and PUMSTO so that the pump-generate cycles may be evaluated. Once these have been developed, the program returns to subroutine SETUP which regards these cycles and their associated effect on spinning reserve just as another load modifier.

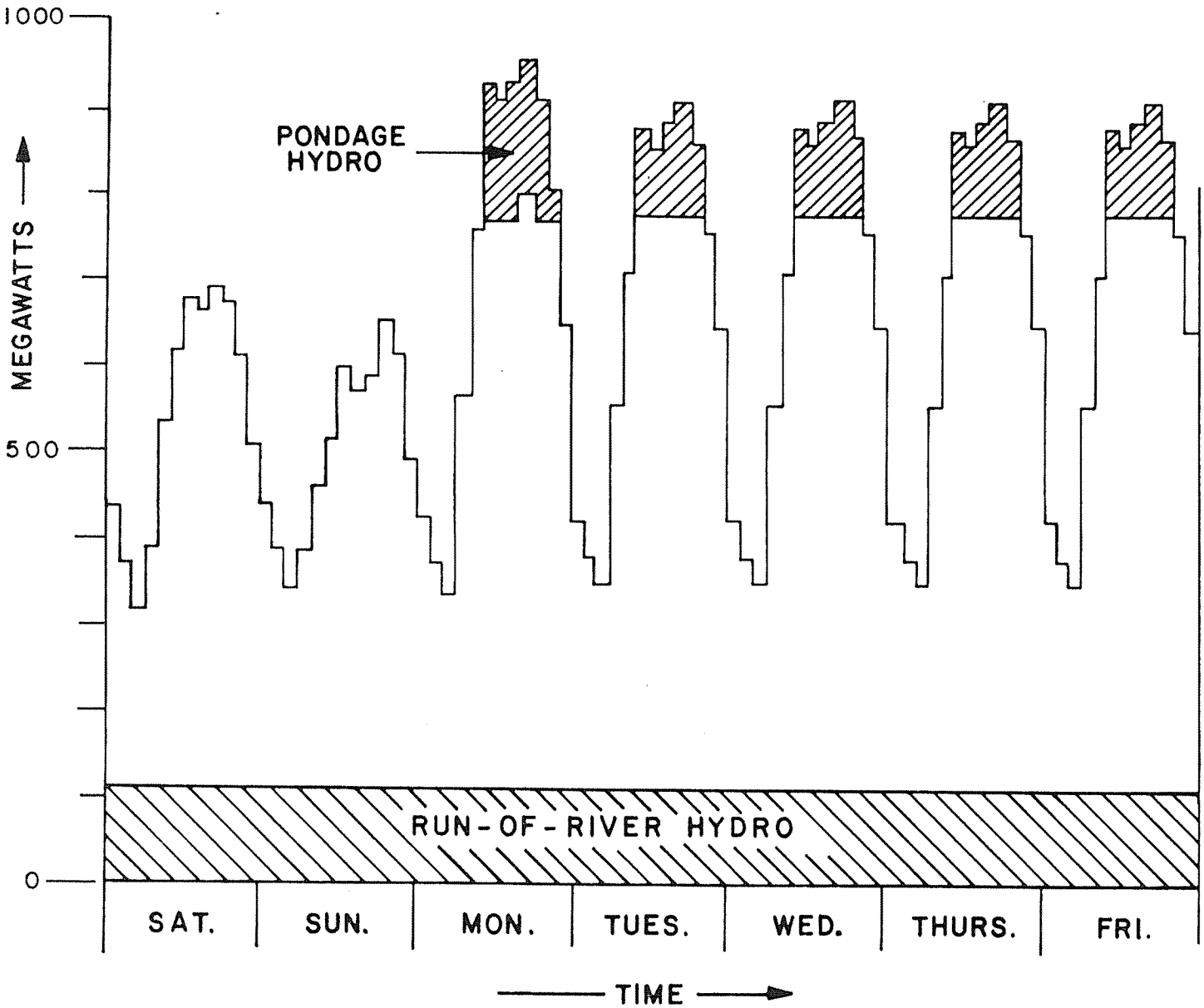
Subroutine-PUMSTO

Subroutine PUMSTO is used to develop the pump-generate schedule. The schedule of the pumped storage units modifies the load shape to be served by the thermal units.

Subroutine-DECIDE

The function of this subroutine is to decide how much of the seven day period developed by subroutine SETUP can be scheduled and costed. It does this by assigning a value to the variable "NOW" which, as can be seen from Figure D-1, will be tested later to determine the proper return

MODIFICATION OF LOAD CYCLES TO REFLECT HYDRO AND CONTRACTUAL PURCHASES AND SALES



- CONTRACTUAL PURCHASES AND SALES CAN BE TREATED IN THE SAME FASHION AS RUN-OF-RIVER HYDRO OR PONDAGE HYDRO.
- A CONTRACTUAL SALE TREATED AS PONDAGE HYDRO CAN BE SCHEDULED EITHER AS AN ADDER TO THE PEAK OR VALLEY LOADS

FIGURE D-4

location for the program. The values that can be assigned to NOW and their significance are:

- NOW = 0 A full seven day step may be taken. This step may or may not close out a calendar month. An additional test is required to check this.

- NOW = -1 A full seven day step cannot be taken because it would terminate in the succeeding month.

- NOW = +1 This value is assigned only if the units available for service change within the week. This can be caused by the installation or retirement of a new unit in midweek or by short term maintenance on a certain unit or units.

Subroutine-COMMIT

After appropriate load and spinning reserve adjustments have been made for pondage hydro, contractual purchases and sales represented as pondage hydro, and for pumped storage, the amount of thermal capacity that must be committed to service is then known for all hours in the period under consideration. Subroutine COMMIT uses this information plus the priority list after modification for unit maintenance to fix the identity of the units that must be on line for each hour. As noted in Figure D-5, the preliminary commitment is made ignoring the minimum down time of the units. This preliminary schedule is then reviewed to check for violations of minimum down time rules. If violations are found, the schedules are corrected as shown in Figure D-5. In making checks for down time violations, if a unit is found that cannot be shut down, program logic assumes that the units of higher priority also cannot shut down. Because of this, care must be taken in setting up the priority order and unit minimum down times so that the minimum down time of any unit does not exceed that of a unit of higher priority.

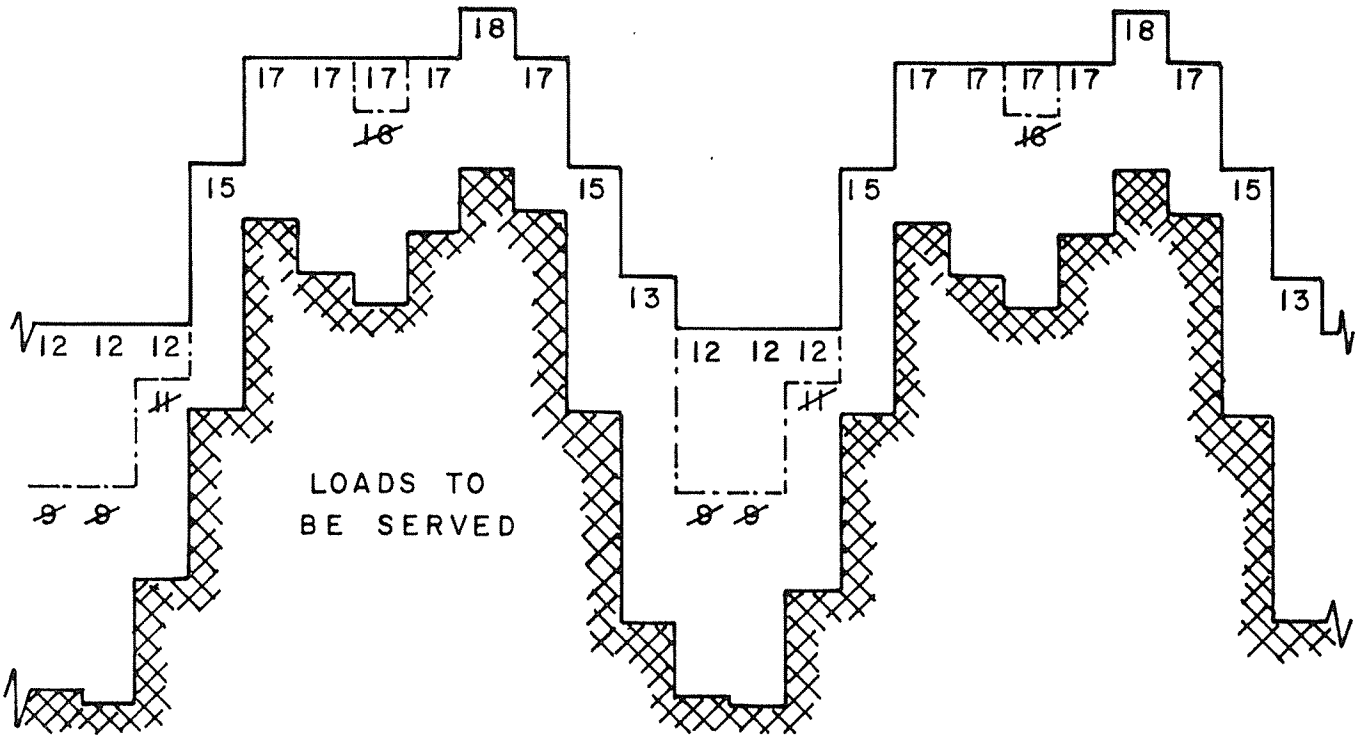
After the commitment schedule has been established, unit starts and the costs associated therewith are treated as shown by Figure D-6

At this point in the program the user has the option to dispatch the system using a deterministic dispatch or a stochastic dispatch.

Subroutine-SKEDUL

After the thermal load pattern and the thermal commitment schedule have been derived, subroutine SKEDUL is used to fix the hour-by-hour dispatch of the system and to cost

COMMITTMENT OF THERMAL UNITS



PRELIMINARY OR MINIMAL COMMITTMENT

FINAL OR REVISED COMMITTMENT

IN THE PRELIMINARY COMMITTMENT

$$\sum_{n=1}^{N} P_{CONT_n} \geqq \text{LOAD}$$

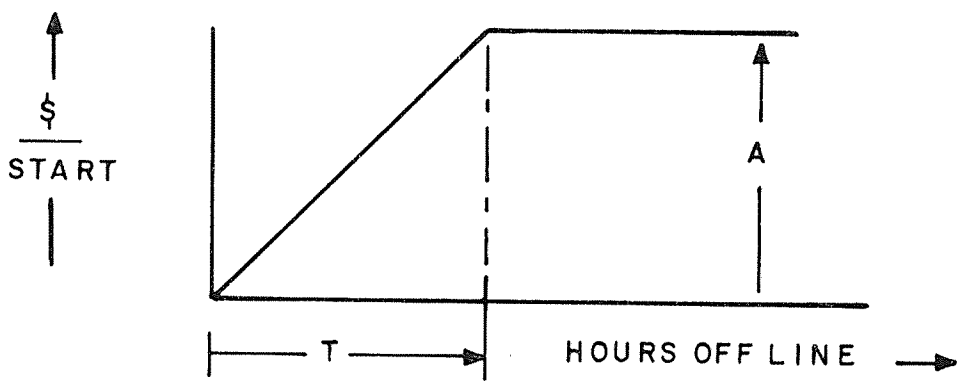
$$\sum_{n=1}^{N} P_{MAX_n} \geqq \text{LOAD} + \text{SPINNING RESERVE}$$

IN THE FINAL COMMITTMENT, IN ADDITION TO THE ABOVE, MINIMUM DOWN TIME RULES ARE MET.

COSTING UNIT STARTUPS

FOR EACH UNIT, THE NUMBER OF STARTS ARE CUMULATED ON A MONTHLY AND ANNUAL BASIS.

THE COST OF EACH UNIT STARTUP IS CALCULATED AS FOLLOWS:



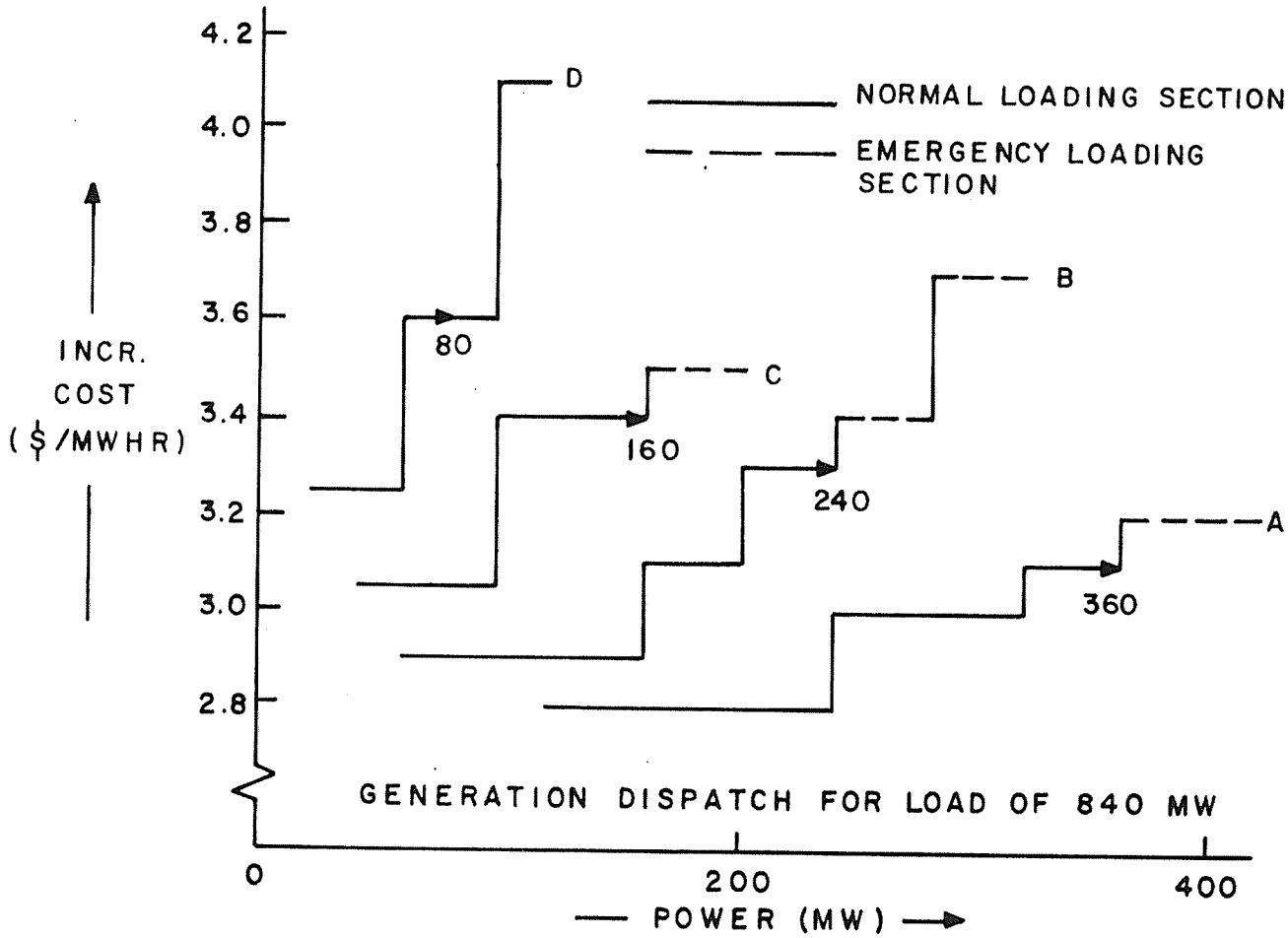
THE QUANTITIES A & T MUST BE GIVEN AS INPUT DATA FOR EACH UNIT. THESE ARE:

T = OFFLINE HOURS EQUIVALENT TO COLD START

A = $ / COLD START

FOR EACH UNIT, STARTUP COSTS ARE CUMULATED ON A MONTHLY AND ANNUAL BASIS.

STEP INCREMENTAL SCHEDULING



- LOADING OF EMERGENCY SECTIONS IS NOT DONE, EVEN IF ECONOMIC, UNLESS THERE IS NO OTHER WAY POSSIBLE TO MEET LOAD.
- INCREMENTAL COSTS CAN BE MODIFIED BY PENALTY FACTOR IF DESIRED.
- AN EMERGENCY LOAD SECTION IS NOT REQUIRED

the resulting dispatches. Scheduling is done on a step incremental basis using penalty factor and O&M modification if this is desired. Figure D-7 shows the manner in which the dispatch for a given hour would be developed by the program.

Subroutine-RANDOM

If a stochastic dispatch of the thermal system is desired, subroutine RANDOM is called.

The load uncertainty and multi-state analysis are included during the stochastic dispatch.

A method of approximating unit forced outages (unit deration) is used. Under some circumstances, the option is a good approximation to the stochastic dispatch. In addition, the run time is reduced considerably.

Next the value of "NOW" is tested to find out if the week has ended, if conditions have changed, or if the month is complete. If it is not the end of the month, the program cycles back to PRIORT to complete the months calculations.

Subroutine-MONSUM

If the month is complete, subroutine MONSUM is called in order to print out a summary of performance and cost for the calendar month just completed.

Subroutine-FUELM

Each month and annually three additional summaries may be printed. One summary combines fuel cost, O&M cost and energy output by generation type. A second summary tabulates fuel used, fuel cost, energy output and inventories by plant. While the third lists energy output, fuel cost, fuel used, and energy cost by fuel type.

Subroutine-ANNSUM

At the end of each year, subroutine ANNSUM is used to develop a summary of the years' operation. As in the monthly summary, this is done on a unit and on a system basis. Present worth calculations are carried out on the system cost totals at this point. Subroutine FUELM is called to print the annual summaries described above, then the program returns to read annual data for the next year to be calculated.

In closing, one point should be noted concerning purchases. A purchase can be made by defining the purchase as a unit of the system with a cost characteristic and priority position just as a normal unit would have. Using this method, economics govern the energy purchased and proper costs will be calculated. However, using this approach there is no way to control the total amount of energy purchased.

APPENDIX E

APPENDIX E

APPLIANCE DUTY CYCLES

E.1 Introduction

This appendix summarizes the data, assumptions and methods employed in developing daily appliance duty cycles and estimating the percent of appliance energy use that occurs during the peak demand periods for the reference electric utilities.

E.2 Space Conditioning

Space conditioning values were generated using a computer simulation developed by Arthur D. Little as part of another project*. This program uses actual weather tapes as inputs to predict heating and air conditioning loads for a typical 1,500 ft^2 ranch house.

For this report we selected weather tapes for a representative northern and southern city based on population weighted heating and cooling degree days using data from Reference 17 (Westinghouse). This study divided the country into north and south regions using the 37.5^{o} latitude as the dividing line and developed population weighted data on a state by state basis. Their data is shown in Table E.1. Also shown are a population weighted total for the U.S. and data for New York City and Fort Worth, Texas for a reference year for which weather tapes were available. Based on this data, the space conditioning requirements for New York and Fort Worth were selected as being representative of a northern and southern utility area respectively. The actual monthly load curves (see Tables E.2 & E.3) were normalized to give a yearly energy consumption on a per customer basis equal to the estimated use shown in Chapter 2.

E.3 Appliance Duty Cycles

Duty cycles for each of the appliances other than the space heater and air conditioner are discussed separately below. In most cases, a peak time and range were selected for the appliance and the usage was distributed using the standard normal curve. Table E.4 shows the described cycles below. Clothes washers and dryers were assumed to be used Monday through

* Reference 18 (Solar Climate)

TABLE E.1

HEATING AND COOLING LOADS
(kwh Residence)

Space Conditioning Data

	U.S.[1]	North[2]	NYC	South[3]	Fort Worth
Heating Degree Days	4659	5975	4696	2429	2659
Cooling Degree Days	1278	741	1248	2188	2473

1. Population weighted

2. North of 37.5° Latitude

3. South of 37.5° Latitude

HOUR BEGINNING	JAN.* HEATING	FEB. HEATING	MAR. HEATING	APR. HEATING	MAY HEATING	MAY COOLING	JUNE COOLING	JUL. COOLING	AUG. COOLING	SEPT. HEATING	SEPT. COOLING	OCT. HEATING	NOV. HEATING	DEC. HEATING
MN	6.90	4.10	3.90	1.40	0.60	0.0	0.0	0.0	0.17	0.0	0.0	0.62	1.93	4.76
1	4.55	4.36	3.31	1.90	0.29	0.0	0.0	0.0	0.0	0.0	0.0	1.16	3.13	3.89
2	5.87	4.08	4.15	2.47	0.28	0.0	0.18	0.0	0.0	0.0	0.0	1.40	2.14	4.70
3	5.78	4.24	3.92	2.62	0.90	0.0	0.0	0.0	0.0	0.0	0.0	0.65	2.69	3.82
4	6.09	3.97	3.95	2.22	0.28	0.0	0.0	0.0	0.0	0.0	0.0	1.08	3.36	5.15
5	4.87	4.31	4.37	1.80	0.55	0.0	0.0	0.34	0.0	0.28	0.0	1.54	2.92	4.18
6	5.63	2.71	2.82	2.95	0.0	0.0	0.52	0.66	0.34	0.0	0.0	0.53	1.42	3.70
7	5.54	3.56	2.60	0.29	0.52	0.0	1.06	0.51	0.35	0.0	0.0	1.12	2.66	3.99
8	2.30	1.59	2.08	1.55	0.0	0.16	0.17	0.68	0.50	0.0	0.50	0.0	0.34	1.76
9	3.09	2.31	0.57	0.27	0.0	0.0	0.17	0.66	0.64	0.0	0.53	0.0	0.58	2.07
10	3.05	0.67	2.80	0.90	0.29	0.0	1.79	2.36	0.67	0.0	0.35	0.0	0.83	1.13
11	2.91	1.58	1.18	0.27	0.0	0.50	0.90	1.52	1.51	0.0	0.69	0.0	0.84	3.12
Noon	2.51	1.61	1.25	0.95	0.0	0.34	1.27	0.87	0.84	0.0	1.57	0.0	0.26	1.77
1	3.20	2.61	1.89	0.62	0.32	0.48	1.08	1.73	1.01	0.0	0.87	0.26	0.97	1.76
2	5.12	1.31	1.55	0.88	0.0	0.34	1.77	1.72	1.19	0.0	0.54	0.27	0.61	2.33
3	3.99	4.19	0.93	0.54	0.0	0.16	0.90	1.38	1.70	0.0	0.52	0.0	1.19	3.63
4	5.21	2.39	3.09	1.51	0.32	0.33	0.69	1.70	0.0	0.0	0.37	0.31	1.24	2.64
5	6.04	3.23	1.83	0.62	0.0	0.17	0.90	0.33	0.17	0.0	0.17	0.61	2.34	3.84
6	3.21	3.38	1.25	1.78	0.26	0.0	0.53	0.52	0.17	0.0	0.35	0.0	2.11	2.42
7	5.20	3.46	2.51	0.86	0.28	0.0	0.17	0.52	0.66	0.0	0.36	0.57	1.35	3.37
8	5.74	2.93	2.30	0.92	0.0	0.0	0.18	0.81	0.17	0.0	0.0	1.13	1.80	3.23
9	4.73	5.48	2.73	1.55	0.30	0.0	0.17	0.35	0.16	0.0	0.15	0.28	1.71	3.97
10	6.25	3.90	3.80	2.20	0.58	0.0	0.17	0.0	0.0	0.0	0.0	1.12	2.93	4.26
11	5.72	3.70	1.89	2.19	0.0	0.0	0.0	0.17	0.0	0.0	0.17	1.27	1.88	3.22
TOTAL...	113.5	75.67	60.67	33.26	5.77	2.48	12.62	16.83	10.25	0.28	7.14	13.92	41.23	78.71

* NOTE: All loads Kwh

TABLE E.2: SPACE CONDITIONING LOAD FOR WINTER PEAKING AREA (NEW YORK CITY)

	JAN* HEATING	FEB HEATING	MAR. HEATING	APR. HEATING	MAY COOLING	JUNE COOLING	JULY COOLING	AUG. COOLING	SEPT. COOLING	OCT. HEATING	OCT. COOLING	NOV. HEATING	DEC. HEATING
MV	3.93	1.25	1.18	0.84	0.0	0.0	0.87	0.17	0.0	0.64	0.0	2.09	1.59
1.	3.71	1.54	3.02	0.58	0.0	0.0	0.52	0.17	0.0	0.29	0.0	0.71	2.01
2.	3.78	2.11	1.69	0.66	0.0	0.0	0.35	0.17	0.0	0.68	0.0	2.79	2.72
3.	3.31	2.07	1.80	0.44	0.0	0.0	0.35	0.35	0.0	1.06	0.0	2.94	2.79
4.	4.47	1.30	2.85	1.33	0.0	0.0	0.17	0.0	0.0	0.66	0.0	2.70	3.13
5.	3.04	2.17	3.03	0.94	0.0	0.17	0.52	0.0	0.0	0.57	0.0	1.50	2.53
6.	3.71	1.54	1.09	0.73	0.0	1.42	1.55	1.55	0.17	0.64	0.0	2.72	1.46
7.	3.25	0.88	0.26	0.92	0.17	1.26	1.57	1.20	0.54	0.0	0.0	1.29	4.04
8.	1.65	0.0	1.73	0.33	0.52	1.06	1.23	1.39	0.71	0.26	0.0	0.85	0.58
9.	2.17	0.97	0.55	0.27	0.16	1.08	2.30	1.05	0.53	0.0	0.0	1.28	1.18
10	2.65	0.33	0.94	0.37	0.17	1.45	1.59	2.79	1.08	0.0	0.17	0.60	0.0
1	2.19	0.33	0.61	0.0	0.87	1.82	1.98	1.76	1.09	0.28	0.67	0.95	0.28
	1.98	0.33	0.69	0.58	0.69	1.82	2.51	2.66	1.96	0.0	0.15	0.53	0.28
1	1.10	0.38	0.82	0.0	0.86	2.01	2.71	2.66	1.95	0.0	0.16	1.31	0.0
2	2.47	0.95	0.76	0.39	0.88	2.37	2.68	2.32	1.10	0.29	0.84	0.86	0.55
3	2.03	0.59	0.89	0.55	1.19	1.81	3.06	2.67	1.08	0.0	0.16	1.31	1.21
4	3.23	0.32	1.32	0.28	0.17	1.83	2.16	1.96	0.91	0.56	0.0	0.89	0.52
5	1.78	1.28	0.95	0.55	0.36	2.18	1.99	2.13	0.55	0.0	0.0	1.50	0.88
6	2.98	0.90	1.17	0.27	0.51	0.72	1.24	1.42	0.69	0.34	0.0	1.00	0.28
7	1.91	0.0	0.58	0.39	0.17	0.72	2.48	1.21	0.54	0.56	0.31	0.85	0.84
8	2.53	0.93	1.11	0.28	0.0	0.90	1.58	1.21	0.36	0.64	0.14	1.45	1.53
9	1.73	0.94	1.63	0.28	0.17	0.88	1.05	1.40	0.17	0.0	0.0	0.85	1.23
10	4.30	1.19	1.14	0.96	0.0	0.71	0.52	0.52	0.17	0.61	0.0	1.19	0.94
11	2.56	1.60	1.62	0.54	0.0	0.0	0.35	0.17	0.0	0.61	0.0	2.84	2.95
	66.46	23.90	31.43	12.48	6.89	24.21	35.33	30.93	13.60	8.69	2.57	35.00	33.52

* NOTE: All value in Kwh

TABLE E.3: SPACE CONDITIONING LOAD FOR SUMMER PEAKING AREA (FORT WORTH)

PERCENT OF DAILY USE IN HOUR FOLLOWING TIME INDICATED

	MN	1	2	3	4	5	6	7	8	9	10	11	N	1	2	3	4	5	6	7	8	9	10	11
CLOTHES WASHERS AND DRYERS									2.5	22.5	22.5	2.5						2.5	22.5	22.5	2.5			
RANGES AND OVENS																2.5	47.5	47.5	2.5					
DISHWASHERS																	2.5	47.5	47.5	2.5				
WINTER LIGHTING							12.5	12.5										0.5	6.5	30.5	30.5	6.5	0.5	
SUMMER LIGHTING																				2.5	47.5	47.5	2.5	
TELEVISION								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	5.0	12.5	17.5	17.5	12.5	5.0	
WATER HEATING						0.2	5.3	5.8	3.2	17.7	3.5	4.6	2.5	4.0	3.5	1.2	3.2	6.6	11.2	15.7	7.5	7.0	1.3	0.3

TABLE E.4 APPLIANCE DAILY DUTY CYCLES

Saturday only. All other appliances were assumed to have 365 cycles/year.

a. Refrigerator/Freezer

The refrigerator/freezer was assumed to have a flat duty cycle, being part of the baseline load in the home.

b. Ranges/Ovens

Data on ranges and ovens indicated very low to no use up until about 3:00 p.m. One study indicated a peak at 6:00 p.m. (23) and another study put it at 4:30 p.m. (21). The peak was chosen as 5:00 p.m., with the use period being from 3:00 p.m. to 7:00 p.m.

c. Dishwashers

Data on dishwashers were compiled from duty cycles on water heaters (18,21,22,23,25,26). Most studies showed dishwashing occurring around 6:00 p.m. to 7:00 p.m. Thus, a peak of 7:00 p.m. was selected with a usage period from 5:00 p.m. to 9:00 p.m.

d. Clothes Washers and Dryers

Based on water heater use data (18,21,22,23,25,26) two washing peaks were identified. The peaks were morning (occurring in households where one parent remained home during the day) and evening (occurring in households where both parents worked). As approximately 50% of all households have two working parents, the usage was assumed equal for both periods. The peaks were selected for 10:00 a.m. and 7:00 p.m. with corresponding periods of 8:00 a.m. to noon and 5:00 p.m. to 9:00 p.m., respectively.

e. Televisions

Only one report included data on television usage (23). The data indicated television usage from 6:00 p.m. to 10:00 p.m. The duty cycle chosen for televisions assumed that 30% of the use occurred during the day due to children and others at home. The remaining 70% occurred from 5:00 p.m. to 11:00 p.m. with a peak at 8:00 p.m.

f. Lights

No data on lighting usage were found. Two types of uses were selected -- winter and summer. For winter, the following assumptions were made:

(1) Lights are on from 6:00 a.m. to 8:00 a.m. and 5:00 p.m. to 11:00 p.m.

(2) 25% of the usage occurs in the morning.

g. Water Heaters

Several references were found on hot water usage in the home (19,21,22,23,25,26). With the exception of reference 23 all references were fairly consistent so an average percentage was selected as representative of the duty cycle.

APPENDIX F

APPENDIX F

OPERATING CHARACTERISTICS OF REFRIGERATION DEVICES

F.1 Introduction

The purpose of this appendix is to present information on the operating characteristics of the refrigeration cycle devices so that the savings which result from the incorporation of storage systems can be better understood. In the following sections, heat pumps and air conditioners are discussed in detail. This discussion includes descriptions of the types of losses which reduce the efficiency of the devices significantly below that of the ideal. Equations are given which have been used to calculate the reduction in energy use when thermal storage systems are used.

F.2 Heat Pumps

Heat pumps sold for residential and commercial applications are used for space heating in the winter and space cooling in the summer. During the winter, heat is extracted from outdoor air and pumped up to the desired temperature levels for heating indoor air. During the summer, the heat pump is reversed and operated as a conventional air conditioner

Regardless of the specific application of the heat pump,the heat pump performance is highly dependent on operating temperature differential. For a typical heat pump during the heating season, the following performance variations with outdoor and indoor temperature changes were reported by Kelley* from manufacturer's data:

- +1.1% increase in COP per 1°F increase in outdoor temperature;
- +1.3% increase in COP per 1°F decrease in return indoor air temperature.

* See Reference 12 (Kelley)

The ideal COP based on the Carnot cycle is given by:

$$COP_{Ideal} = \frac{T\ outdoor}{T_{outdoor} - T_{indoor}}$$

where the indoor and outdoor temperatures are in absolute units.

The actual COP is significantly less than this value due to a number of factors. First, heat exchangers are required which introduces temperature's differences between the air source and sink and the refrigeration cycle working fluid. We have defined a more meaningful definition of "Ideal" efficiency using ideal heat exchangers. These heat exchangers have an effectiveness equal to one which means that the air temperature leaving the exchanger is equal to the temperature of the working fluid in the exchanger. Defining the COP assuming that the evaporator temperature is 10°F lower than the outdoor temperature and the condenser temperature is 100°F (the normal minimum heating temperature) and calculating the COP based on these temperatures gives the result shown in Figure F-1. Also shown in the figure is Kelley's data representing the actual measured efficiency of heat pumps presently sold for residential air-to-air applications. The deviation between the two is due to a number of real machine constraints such as:

- finite size heat exchangers which cause the heat pump to operate at a higher temperature differential than that possible with "ideal" heat exchangers;
- fan power requirements;
- non-ideal compressor efficiencies (typically around 60-70% insentropic efficiency).

If the fan power requirement for maintaining airflow over both the outdoor and indoor heat exchangers and the effect of the non-ideal heat exchangers which cause the refrigeration unit to operate at higher temperatures on the condensing side in order to reject the heat and lower temperatures on the evaporator side to absorb the heat are included, the COP drops to the level shown in Figure F.2.

If the non-ideal features of a compressor are added, the final COP drops to the level shown in Figure F.3. Also shown in this figure are the range of reported COP's for air-to-air heat pumps presently sold in the United States. Our estimate of the performance of real components lies somewhat lower than the average heat pump sold in the United States because of the heat exchanger characteristic we chose Reference 13 (Hiller).

The heat pump efficiency discussed above was based on steady state conditions. Three non-steady state factors affect the actual Seasonal

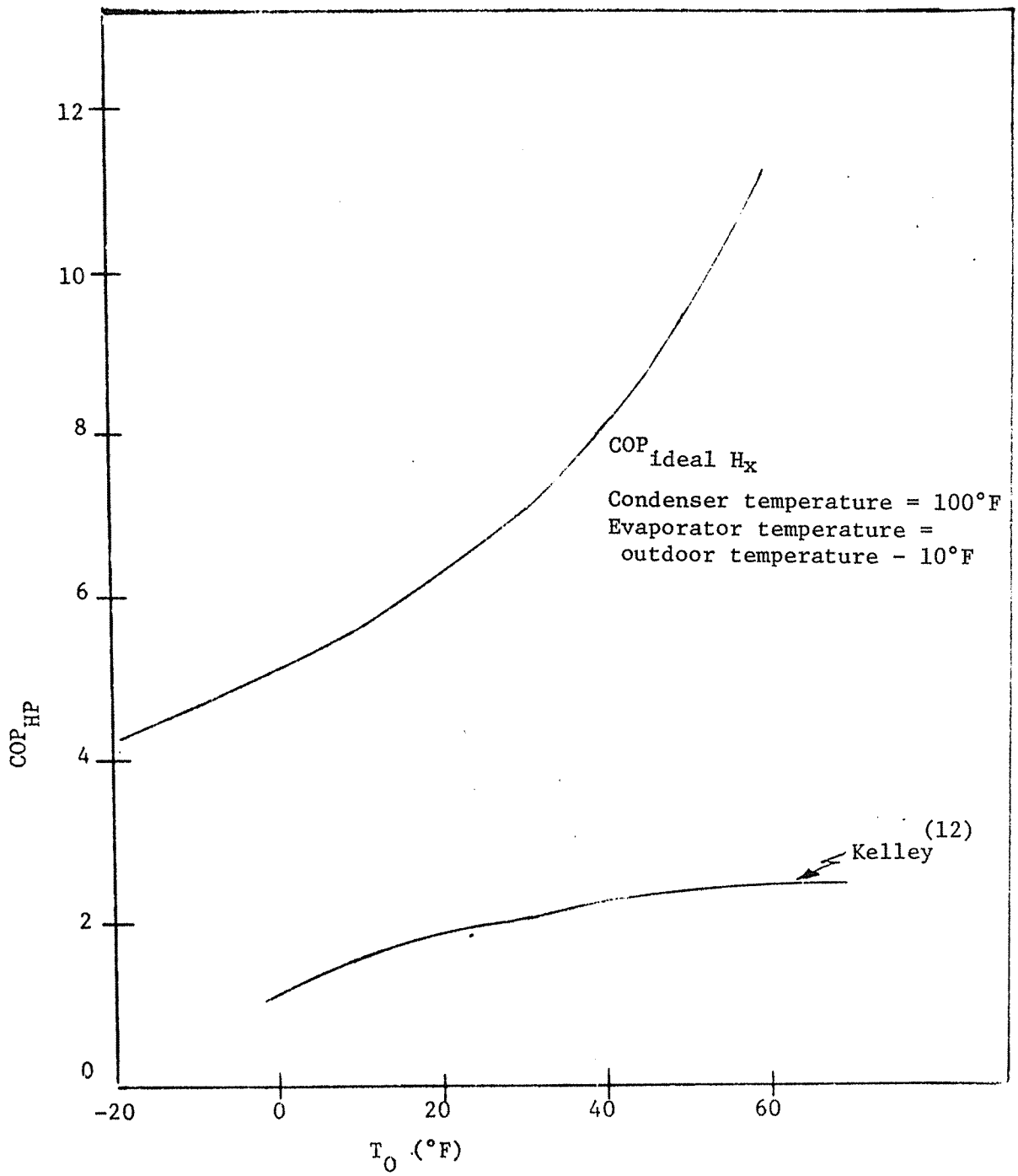


FIGURE F.1 RELATIONSHIP BETWEEN HEAT PUMP COP AND OUTSIDE AIR TEMPERATURE

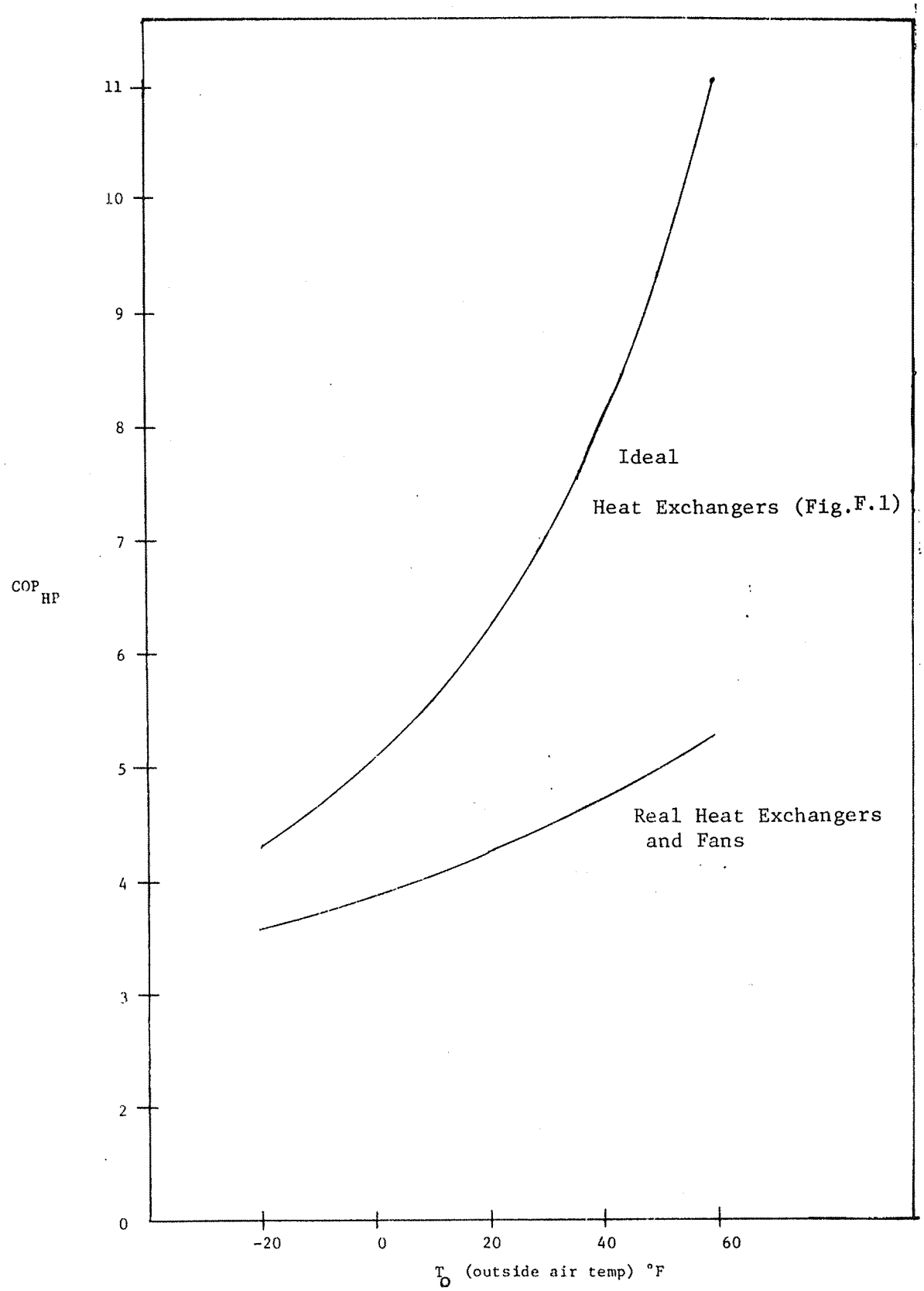
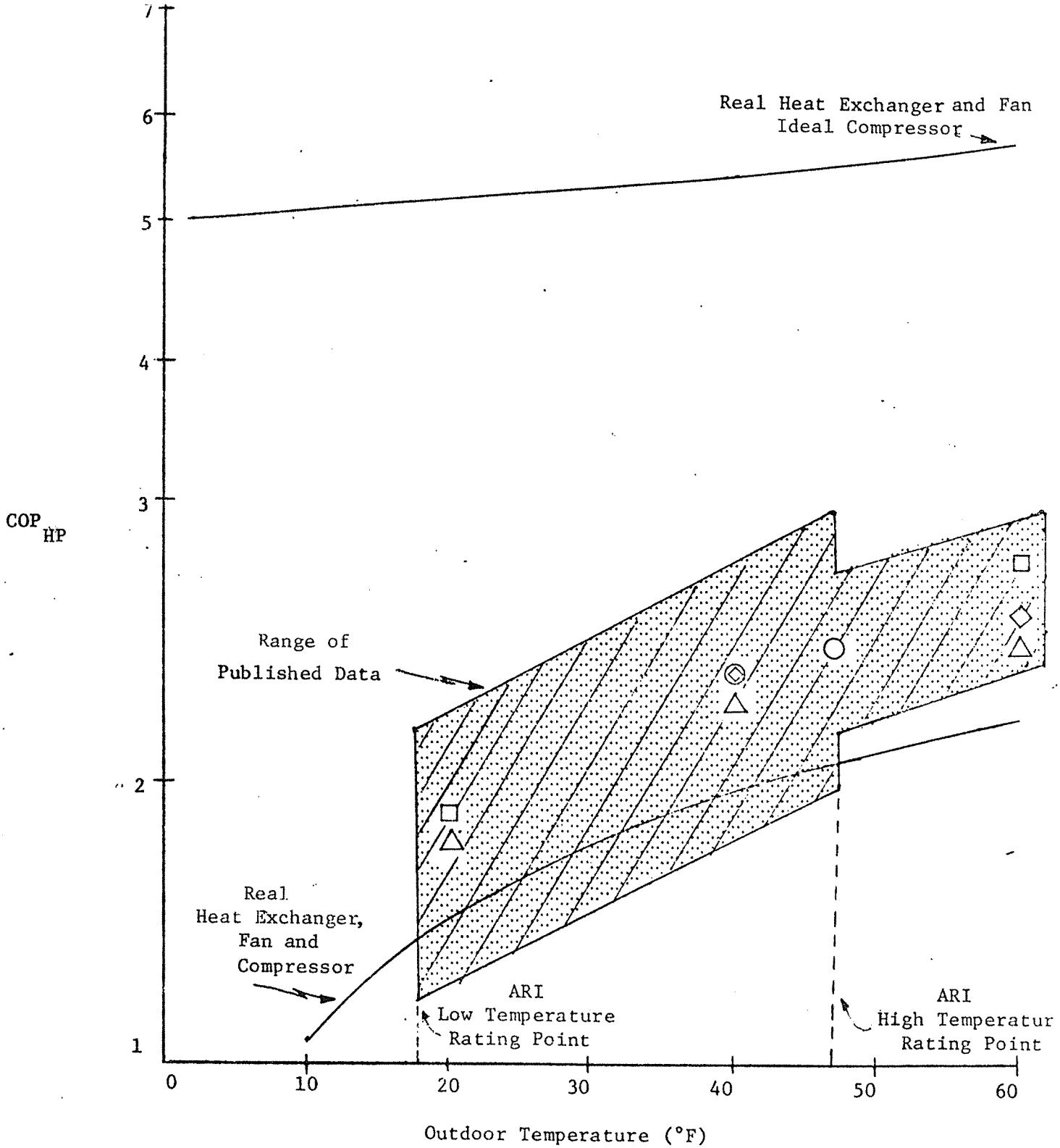


FIGURE F.2 EFFECT OF REAL HEAT EXCHANGERS ON HEAT PUMP



Representative Heat Pumps

Symbol	Capacity Btu/hour
□	65,000
△	45,600
○	34,000
◇	30,000

FIGURE F.3 ACTUAL HEAT PUMP PERFORMANCE

Arthur D Little, Inc.

Performance Factor (SPF) defined as the total seasonal heating divided by the total energy consumption. These factors are:

1) Supplemental electric resistance heating is required when the heat pump capacity is unable to keep up with the heating load;

2) During mild, humid, outdoor conditions, the outdoor coil will accumulate frost which limits heat exchange and must be removed using energy which does not contribute to the useful space heating;

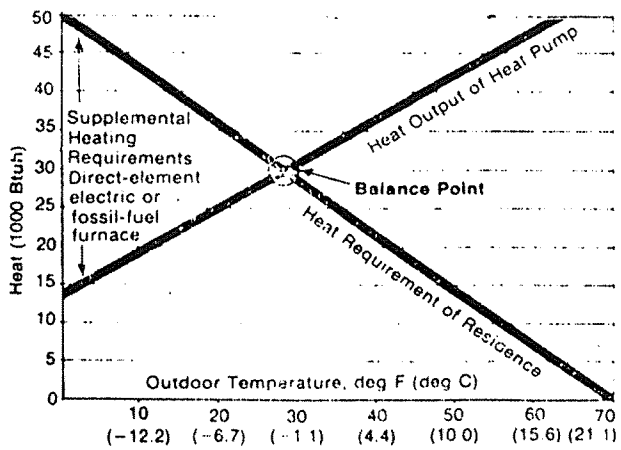
3) Cycling of the heat pump causes energy losses due to the cooldown of the heating coil and warming up of the outdoor coil when the unit is turned off.

As the outdoor temperature falls, the capacity of the heat pump also falls while the heating requirement of the building rises. This is shown in Figure F.4. At the cross-over point or the "balance point," the heat pump must be operated continuously in order to keep up with the heating requirement. At temperatures beneath this balance point, auxiliary electric resistance heating is required. At these lower temperatures, the COP of the heat pump begins to approacn that of an electric resistance system.

When the outdoor temperature is approximately 40 degrees, the outdoor coil temperature is generally below freezing and frost accumulates on the outdoor coil. Most heat pumps defrost the outdoor coil by reversing the cycle temporarily (two to ten minutes) to provide warm refrigerant to the outdoor coil to melt the frost. This causes an energy loss since the heat pump is using power but is not delivering useful heating. The number of defrosts depends on the outdoor air temperature, humidity, and wind speed. Depending on the outdoor temperature, the annual effect of defrost may add between 5 and 10% additional energy cost to the heat pump when reverse cycle defrost is used.* In applications where oversized heat pumps can be used, the percent runtime during the frosting temperature between 40 and 50°F is sufficiently small, so that the outdoor coil can passively defrost during the long off cycle without the use of reverse cycle energy consumption. This type of defrost is not common but has the desirable effect of reducing the energy consumption while minimizing the number of reversing cycles required for the heat pump.

Each start and stop of the heat pump has a loss of efficiency associated with it. The two main causes of this transient loss are:

* Reference 15 (GE)



***Comparison** of heat pump output to the heating requirements of a typical residence. Heat pump output and residential heating requirement intersect at a "balance point," which is typically between an outdoor temperature of 25 and 30 F (−3.9 and −1.1 C). When outdoor temperatures fall below the balance point, it is necessary to add supplemental heat. This heating in typical heat pump applications is provided by direct-element electric heaters.*

Source: Reference 14 (Appliance Manufacturer)

FIGURE F.4 COMPARISON OF HEAT PUMP OUTPUT AND TOTAL REQUIREMENT

- heat stored in the indoor coil is allowed to cool down and dissipate into a non-useful space, and

- each compressor start must separate the refrigerant from the lubricating oil within the system which requires energy and time causing a small but noticable system loss in performance each start up.

The net effect of the defrost and the start up and stop requirements on a heat pump are shown in Figure F.5.

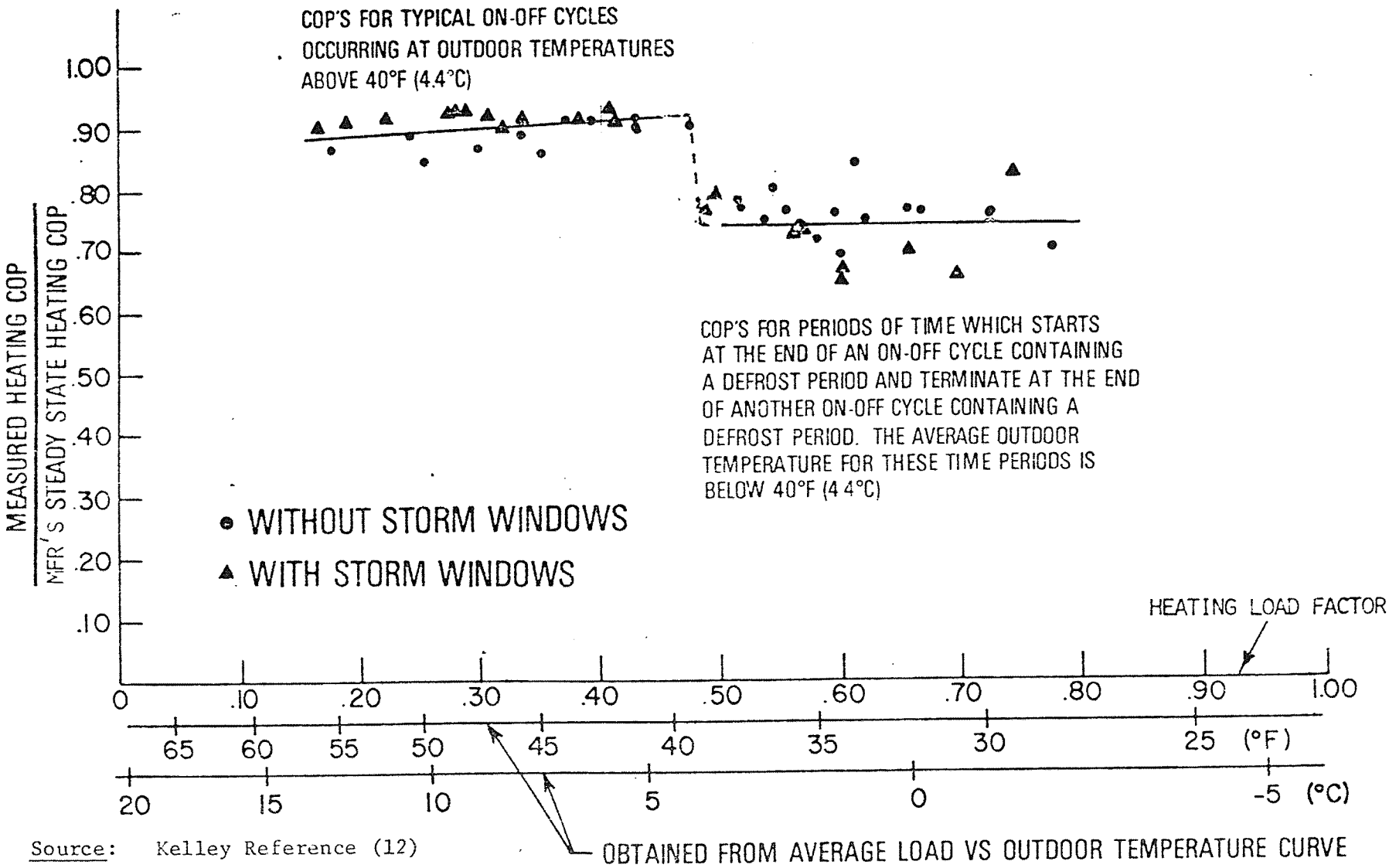
The energy cost of defrost, start and stop, and the auxiliary electric resistance heating lowers the SPF from an average value of 2-2.5 down to 1.5-2.0. An overall breakdown of the penalties incurred by "real-life" heat pump components is presented in Figure F.6.

Most heat pumps used in the United States locate the compressor unit outdoors because of the noise associated with compressor operation. Some of the heat rejected by the heat pump which would actually be used for heating indoor air is lost from the hot compressor to the cold outside air. In addition, electrical resistance heaters are sometimes employed to keep the compressor warm to offset some of the adverse start up problems with a cold compressor. This means that additional energy is lost with the compressor located outside. Present American Refrigeration Institute (ARI) test procedures permit the inclusion of the compressor heat as useful space heating if indeed this heat will be usefully provided to the indoor conditions. Some manufacturers have recognized this advantage and have begun to package compressors on the indoor units with sound insulation; however, the compesssor heat rejected indoors in summer may decrease the heat pump cooling capacity.

F.3 Residential Central Air Conditioning

Residential central air conditioner shipments amounted to approximately 1,500,000 units in 1977 and are expected to remain fairly constant in the immediate future. This will result in an increase in the number of installed air conditioners and will significantly impact the electric power industry's peak and total capacity requirements in the future. Air conditioning's seasonal and daily demand characteristics in theory make it particularly attractive to thermal storage.

Central air conditioners are somewhat similar (in size, construction, and components) to heat pumps which were described in detail in the previous section. The basic difference is that air conditioners are not designed to be reversed to operate in a heating mode. This eliminates some complexity and allows the system components to be optimized for air conditioning only operation resulting in somewhat better cooling performance than the heat pump.



Source: Kelley Reference (12)

FIGURE F.5 VARIATION IN HEAT PUMP PERFORMANCE WITH LOAD, HEATING OPERATION

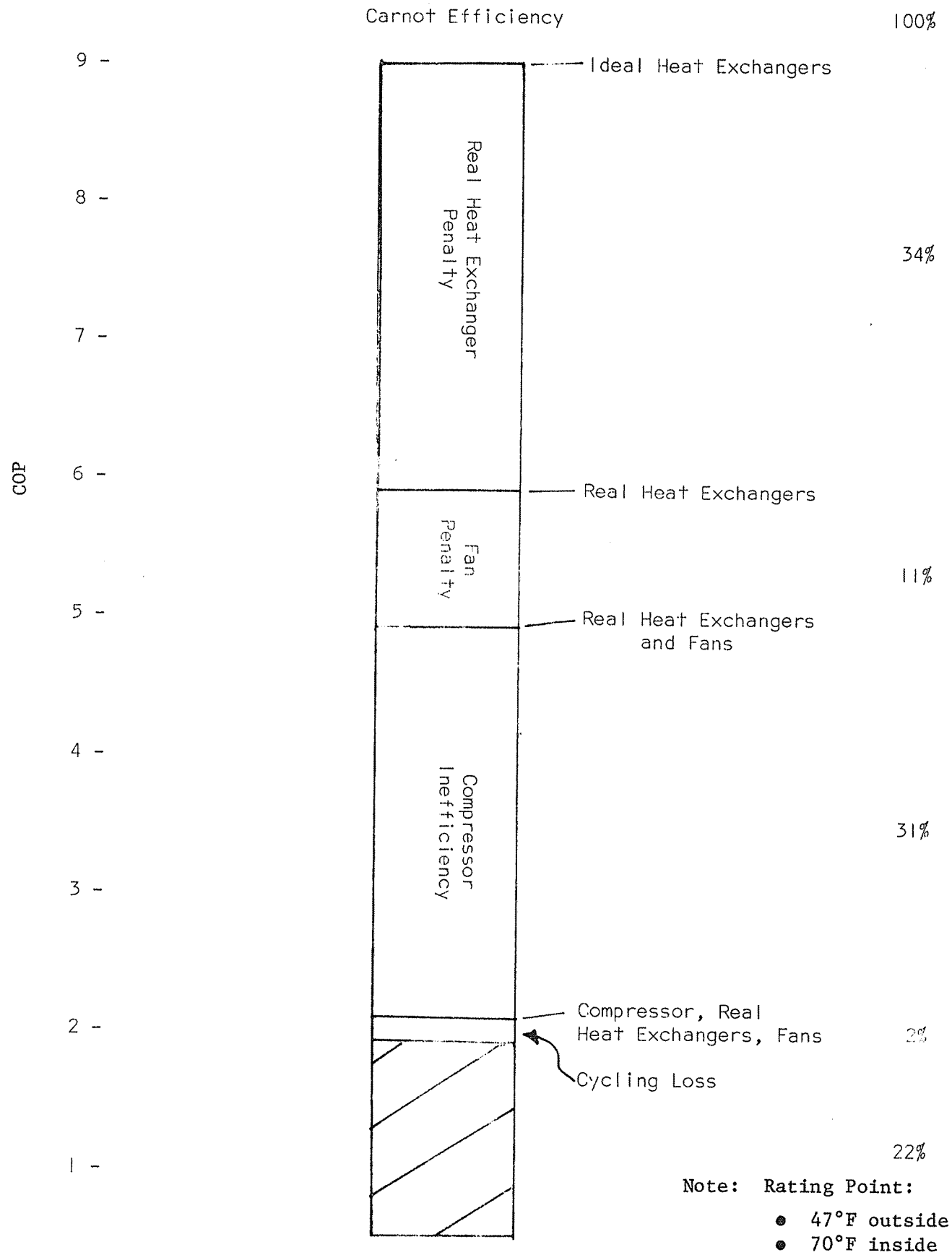


FIGURE F.6 HEAT PUMP ENERGY PARTITIONING

In this study, a conventional, 3 ton, split air-to-air central air conditioner will be considered. The same basic relations also hold for a heat pump operating in the cooling mode that, in general, heat pump cooling performance will be less than for the air conditioner.

An analysis was made of the air conditioner and heat pump (cooling mode) operational characteristics similar to the analysis in the previous section for the heat pump during heating. Curve A of Figure F.7 is the maximum achievable cycle efficiency (Carnot) assuming ideal heat exchangers and reasonable indoor and outdoor temperature differences. Curve B shows the effect of real heat exchangers on performance. Curve C adds the effect of condenser and evaporator fans further dropping actual achievable efficiency. When production compressor characteristics are added, the result is as shown on Curve D. Finally, Figure F.8 is used to determine cycling losses which reduce performance as shown in Curve E of Figure F.7 Here it was assumed that the cooling load factor (cooling requirement/unit steady state output) varies from 0 at 80°F outside temperature (unit off) to 1 at 100°F (unit running continually). The unit steady state COP was corrected by Figure F.8 to reflect losses due to cycling which are caused primarily by:

- heat up of the indoor coil during off time which does not contribute to useful cooling;
- each compressor start in which the refrigerant must separate from the oil which requires energy and time, causing a small but noticeable system performance loss each start up.

Figure F.9 gives an overall breakdown of the "real-life" penalties just discussed at the standard air conditioning rating point (80°F inside, 95°F outside).

F.4 Baseline Air Conditioner/Heat Pump

Air conditioners located principally in the South may have compressor operation of 1200 hours per year over the 5 month cooling season (3,600 hours) or a little more than 33% run time.

If 100% run time corresponds to about 105°F outdoor and 0% run time is 75°F OD, then 33% run time is 85°F assuming a linear relation of run time and outdoor temperature as shown in Figure F. 10

The compressor can be characterized by

$$\dot{m}_r = \alpha T_e + \beta T_c + \gamma \qquad (1)$$

where

$\dot{m}_r$ = refrigerant mass flow rate

T_e = evaporator temperature

T_c = condensing temperature

α, ρ, γ = parameters for a compressor

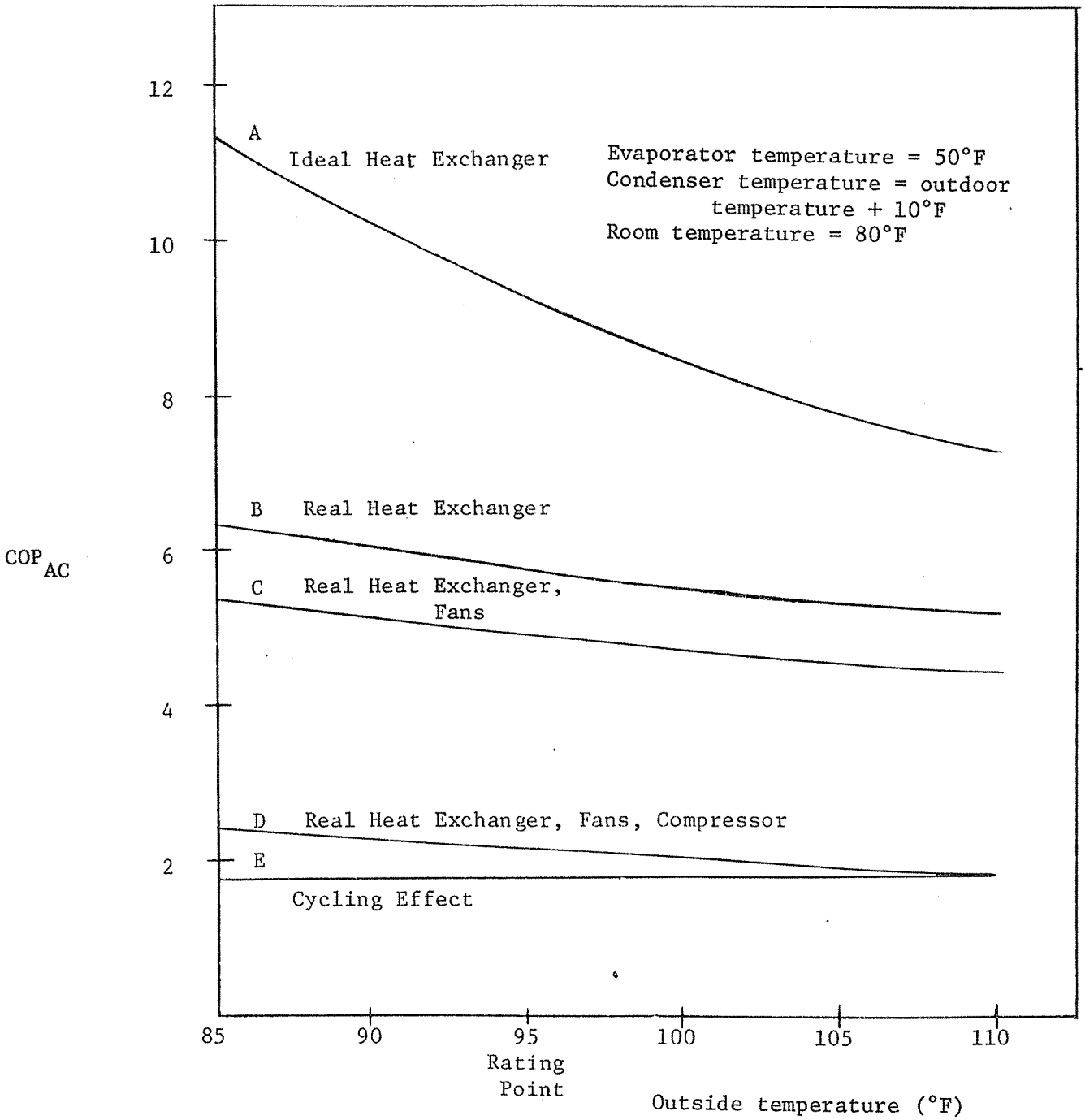


FIGURE F.7 RELATIONSHIP BETWEEN AIR CONDITIONER COP AND OUTSIDE TEMPERATURE

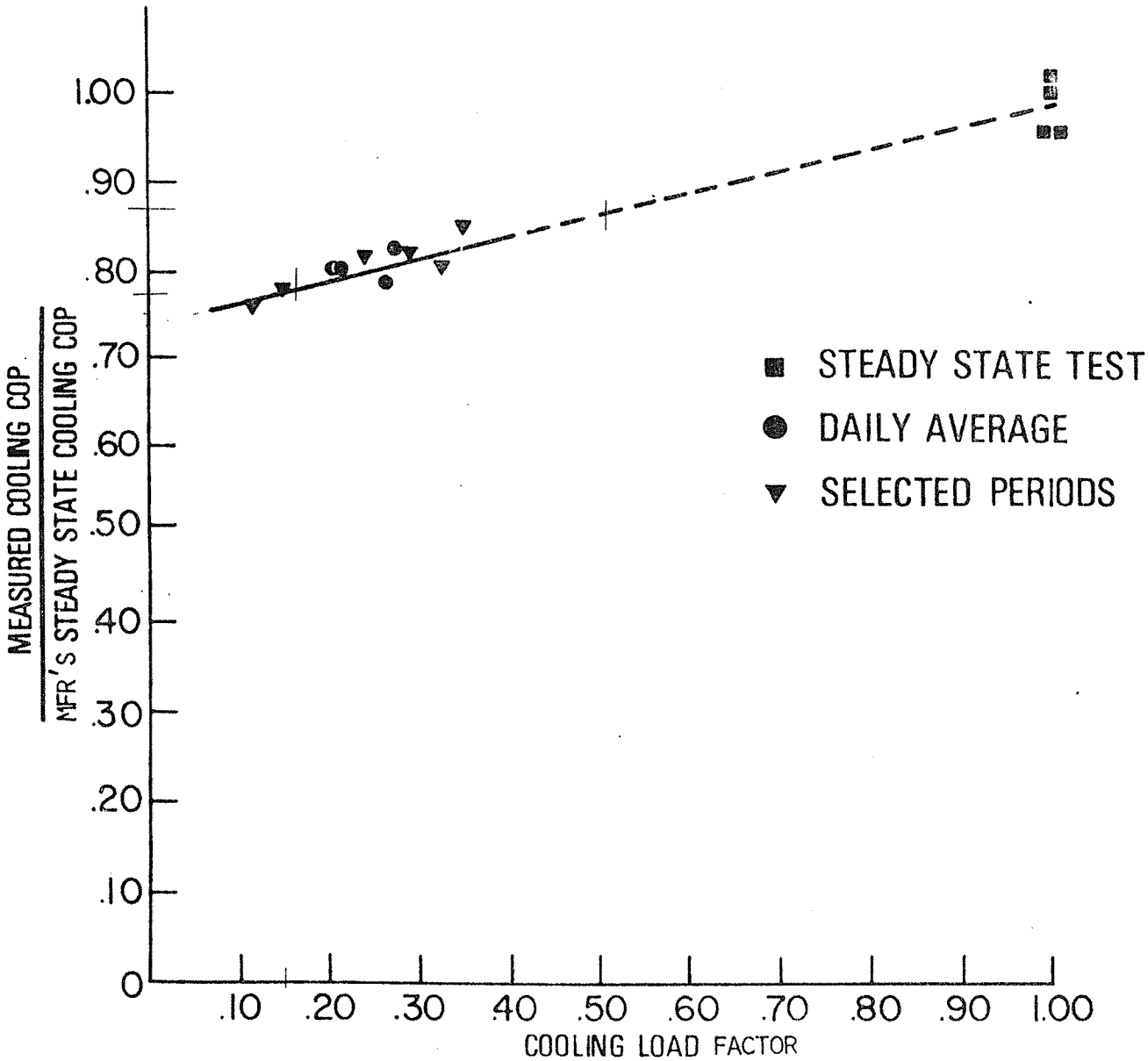


Figure F.8 VARIATION IN PERFORMANCE WITH LOAD, COOLING OPERATION

Reference (12)

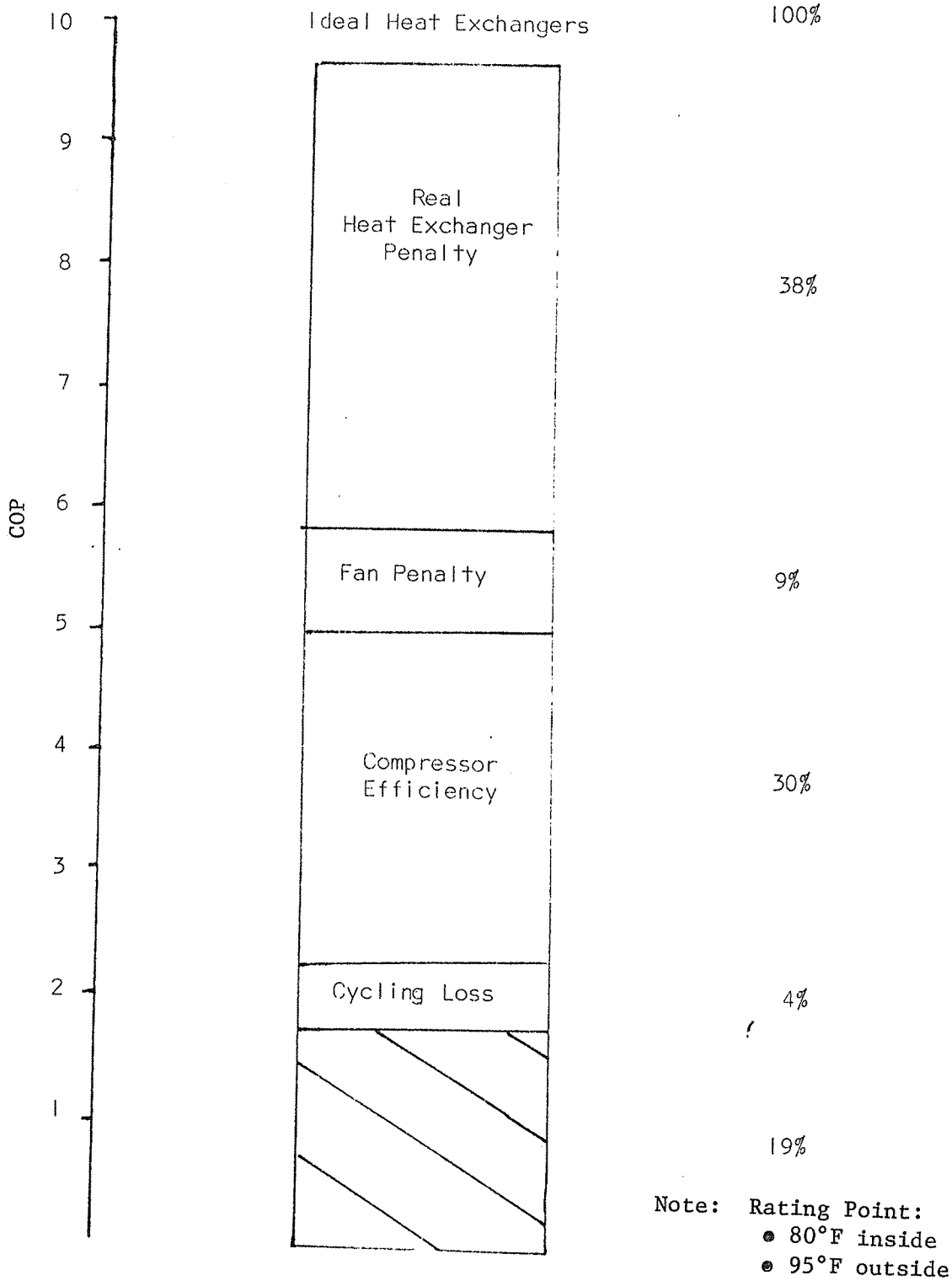


FIGURE F.9 AIR CONDITIONER ENERGY PARTITIONING

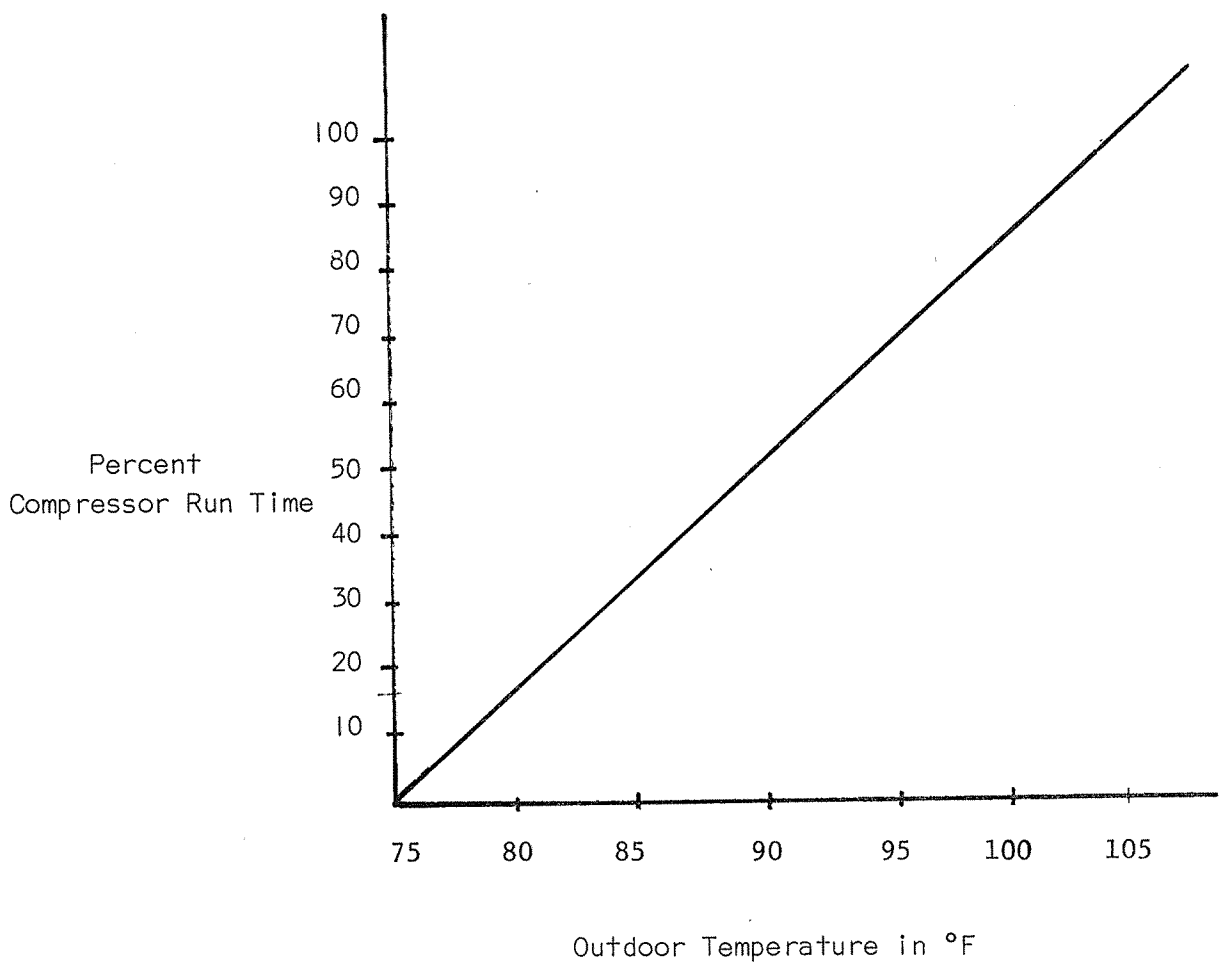


FIGURE F.10 COMPRESSOR DUTY CYCLE

The condenser heat exchanger is characterized by

$$\text{condenser heat rejection} = q_c = \Delta h_{2-3}\ \dot{m}_r = \qquad (2)$$
$$= \varepsilon_c\, C_{ac}\ (T_c - T_{ac})$$

where Δh_{2-3} is the refrigerant enthalpy change in the condenser (Figure F.11).

and: ε_c = heat exchanger effectiveness.

C_{ac} = condenser air heat flow (mass flow rate times heat capacity)

T_{ac} = condenser entering air temperature.

This neglects the difference in heat transfer in the subcooling and desuperheating sections.

Likewise

$$\text{evaporator heat absorption} = q_e = \Delta h_{1-3}\ \dot{m}_r$$
$$= \varepsilon_e\ C_{ae}\ (T_{ae} - T_e) \qquad (3)$$

where Δh_{1-3} = refrigerant enthalpy change in evaporation

ε_e = evaporator effectiveness

C_{ae} = evaporator mass flow rate x heat capacity

T_{ae} = evaporator entering air temperature

For a common compressor:*

Refrigerant mass flow: $\dot{m}_r = 1.4\ T_c + 11.7\ T_e + 211$ (4)

Compressor and fan power: $\dot{w} = .57\ T_c\ T_e - 34.5\ T_e + 3293$ (5)

and under average conditions,** the evaporator enthalpy change is about

112.93 - 45.705 = 67.225 Btu/pound

$$\text{therefore EER} = \frac{\text{cooling capacity in Btu/hr}}{\text{Input watts including fans}} \qquad \frac{\text{Btu}}{\text{hr. W}}$$

$$= \frac{14184 - 94.1\ T_c + 786.5\ T_e}{.57\ T_c\ T_e - 34.5\ T_e + 3293} \qquad (6)$$

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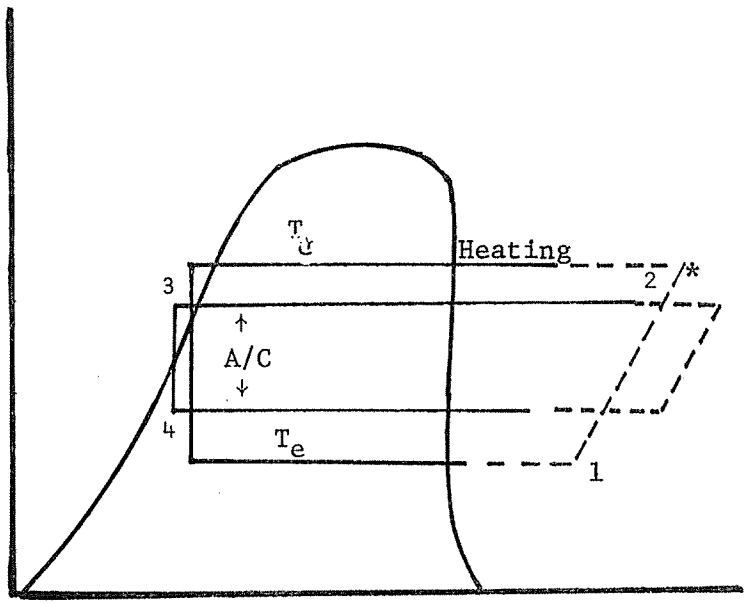
* Copeland Compressor Model # YRB4-0300-PFB.

** Condenser: 120°F; Evaporator: T_{sat} = 43°F with 22° F superheat



* Note: Dashed lines indicate enthalpy change inherent to hermetic compressors. Viewed from a system standpoint it can be neglected.

	Cooling		Heating	
	T	T_{sat}	T	T_{sat}
1	70	43	45	33
2	190	120	150	135
3	110	120	130	135
4	43	43	33	33
T_{ae}	70	--	45	--
T_{ac}	85	--	70	--

FIGURE F. 11 PRESSURE-ENTHALPY DIAGRAM OF A REFRIGERATION UNIT

For a standard* outdoor temperature of 95°F and condenser temperature of 130°F

$$EER = \frac{2737 + 786.5\ T_e}{3293 + 39.6\ T_e} \qquad (7)$$

F.5 Required Temperature of Cooling Coil

The air conditioner must provide dehumidification. This is governed by the enthalpy potential between the cooling coil and the air. In general, to improve efficiency through ΔT modification, the suction temperature must be raised. However, for cooling the air must be dehumidified to provide adequate comfort levels. Thus, for every BTU of sensible heat removed, there must be a certain amount of latent heat removed, or:

$$\frac{q_{sensible}}{q_{latent} + q_{senisble}} = \text{constant}$$

where

$$\frac{q_{sensible}}{q_{latent} + q_{sensible}} = .245 \quad \frac{UA\ (T_{ae} - T_e)}{UA\ (h_{ae} - h_e)}$$

based on the approximations for mass transfer in Stocker.**

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* ARI/ASHRAE Rating Point

** Reference 16 (Stocker)

Also from Stocker:

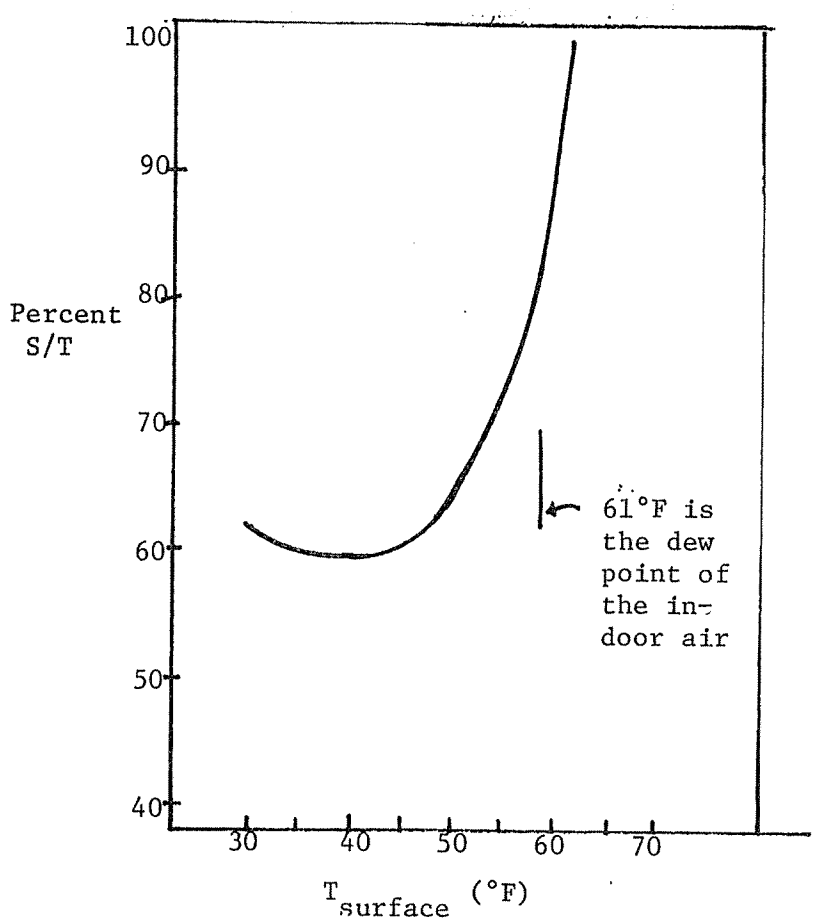
$$h_e = 10.78 - .1885\ T_e + .0075\ T_e^2$$

At the ARI test point, the inside conditions are $T_{db} = 80^oF$. $T_{wb} = 67^oF$, which means that $T_{ae} = 80^oF$ and $h_{ae} = 31.6$; therefore:

$$\frac{q_{sensible}}{q_{total}} = .245 \qquad \frac{80 - T_e}{20.82 + .1885\ T_e - .0075\ T_e^2}$$

where $30 \leq T_e \leq 61$ (^oF)

This relation is given graphically below:



Though the actual sensible/total cooling load requirement will depend on the internal heat generation and outdoor humidity, we can expect the following:

	Design S/T	$T_{surface}$
Northern Climate	85	58
Southern Climate	70	55

Therefore, storage systems should provide a maximum cooling surface temperature of about 55°F.